APPENDIX

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Johansson et al.

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[54] **METHOD OF PRODUCING A NONWOVEN MATERIAL**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[7] **D04H 3/02**; D04H 1/46

[52] **U.S. Cl.** **28/104**; 162/115

[58] **Field of Search** 28/104, 105, 103, 28/106, 107, 167; 162/100, 101, 202, 115, 201, 91, 146, 289, 300, 315, 317, 212; 442/370, 400, 401, 408

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,444,821	2/1970	Evans	161/169
3,849,241	11/1974	Butin et al.	161/169
4,048,364	9/1977	Harding et al.	428/113
4,100,324	7/1978	Anderson et al.	428/288
4,442,161	4/1984	Kirayoglu et al.	28/104
4,443,297	4/1984	Cheshire et al.	162/101
4,537,819	8/1985	Schortmann et al.	28/104
4,591,513	5/1986	Suzuki et al.	28/104
4,623,576	11/1986	Lloyd et al.	428/171
5,106,457	4/1992	Manning	162/115
5,516,572	5/1996	Roe	428/131
5,958,186	9/1999	Holm et al.	162/115

FOREIGN PATENT DOCUMENTS

841938	5/1970	Canada .
308 320	3/1989	European Pat. Off. .
418 493	3/1989	European Pat. Off. .
333 211	9/1989	European Pat. Off. .
333 228	9/1989	European Pat. Off. .
503 059	7/1994	Sweden .
1 329 409	9/1973	United Kingdom .
96/02701	2/1996	WIPO .

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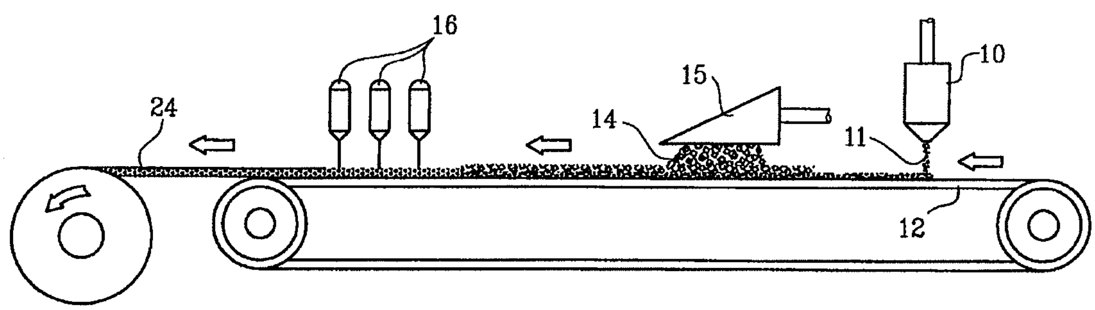
[57] **ABSTRACT**

Method of producing a nonwoven material by hydroentangling a fiber mixture containing continuous filaments, e g meltblown and/or spunbond fibers, and natural fibers and/or synthetic staple fibers. The method is characterized by foamforming a fibrous web (**14**) of natural fibers and/or synthetic staple fibers and hydroentangling together the foamed fiber dispersion with the continuous filaments (**11**) for forming a composite material where the continuous filaments are well integrated with the rest of the fibers.

9 Claims, 8 Drawing Sheets



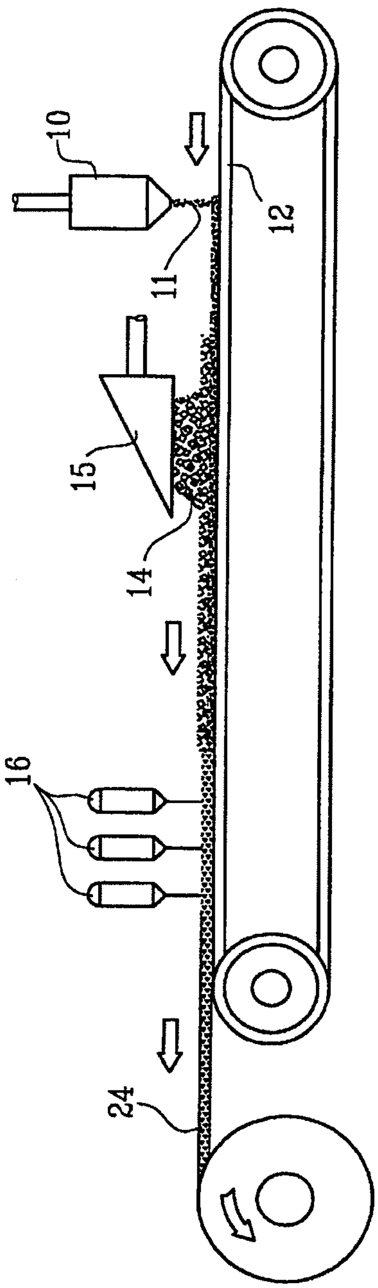


FIG. 1

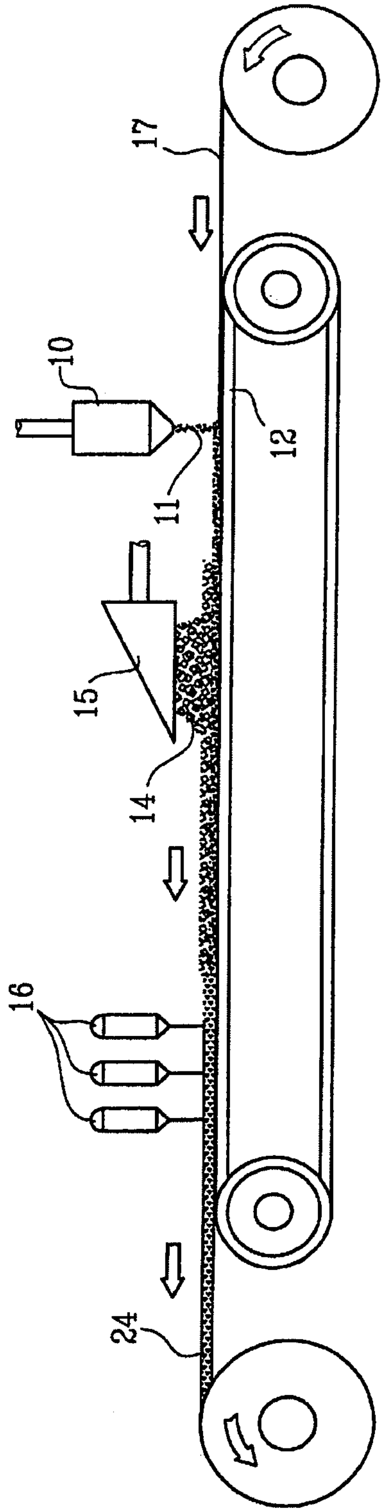


FIG. 2

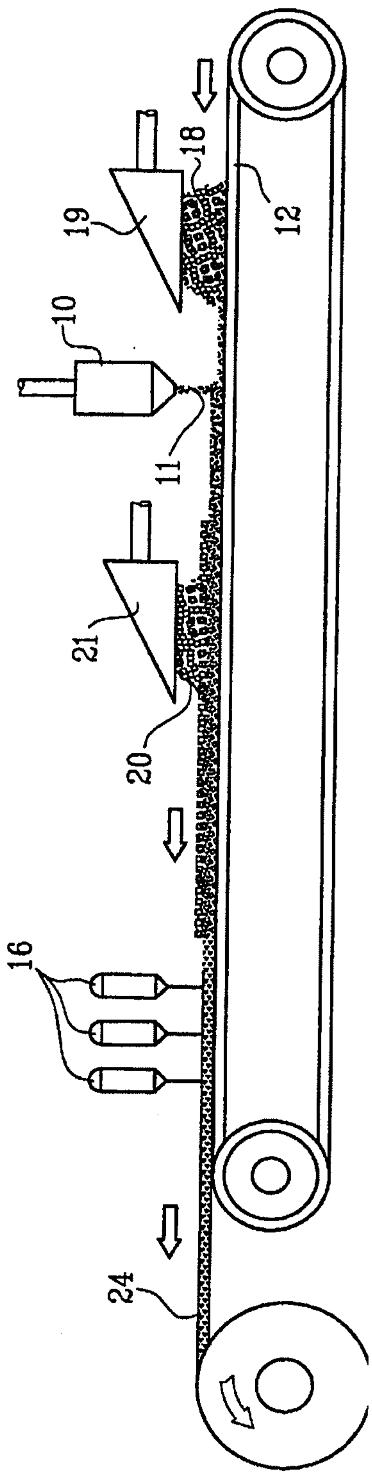


FIG.3

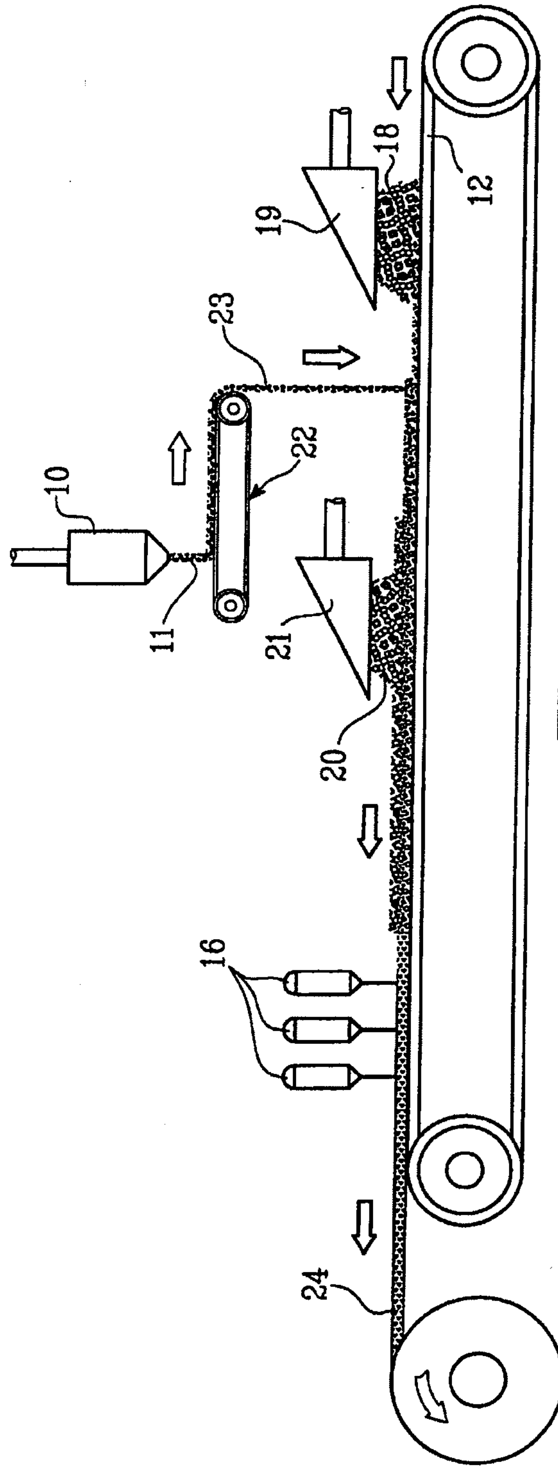


FIG.4

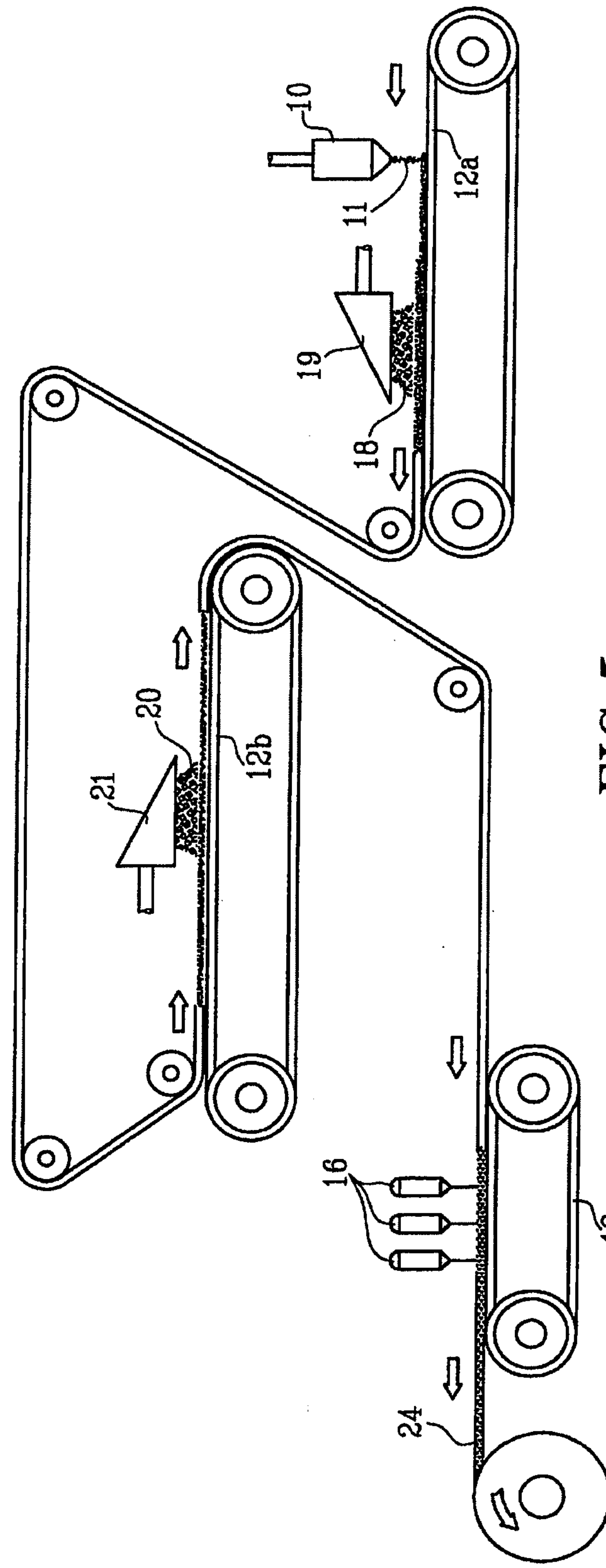


FIG.5

FIG. 6

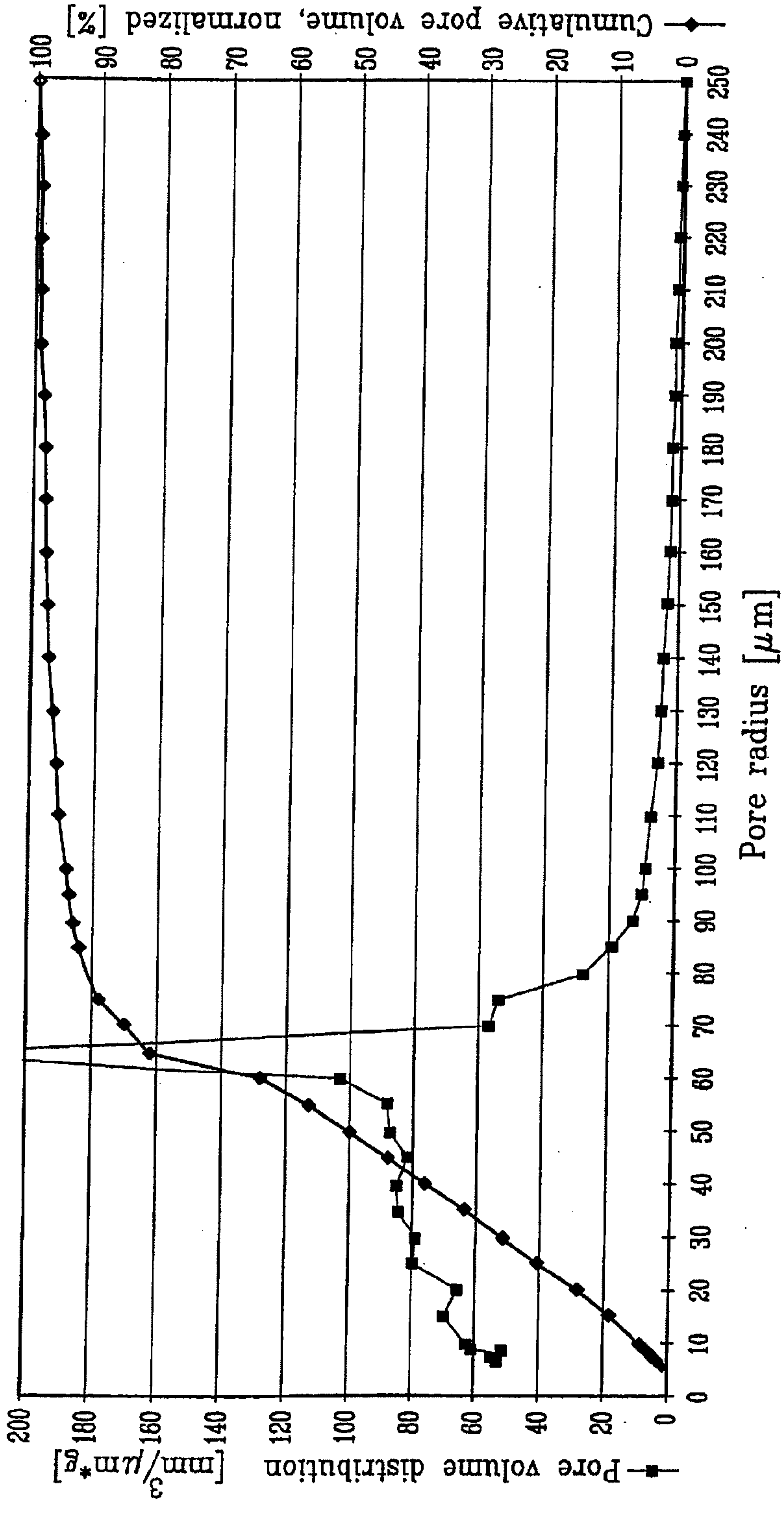

Cumulative pore volume, normalized [%]
Pore volume distribution [mm³/μm*g]
Pore radius [μm]

FIG. 7

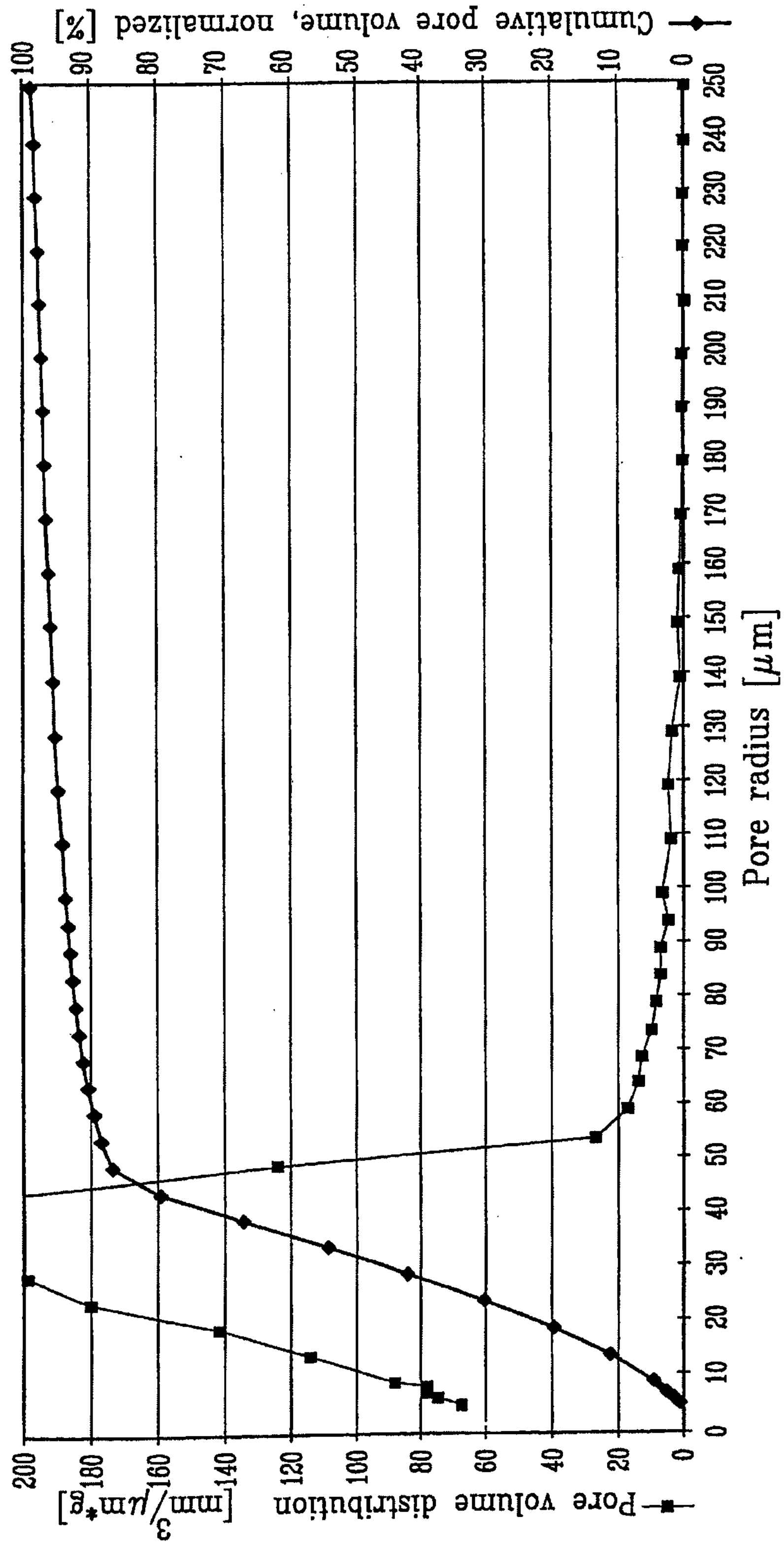

Cumulative pore volume, normalized [%]
Pore volume distribution [mm3/μm*g]
Pore radius [μm]

FIG. 8

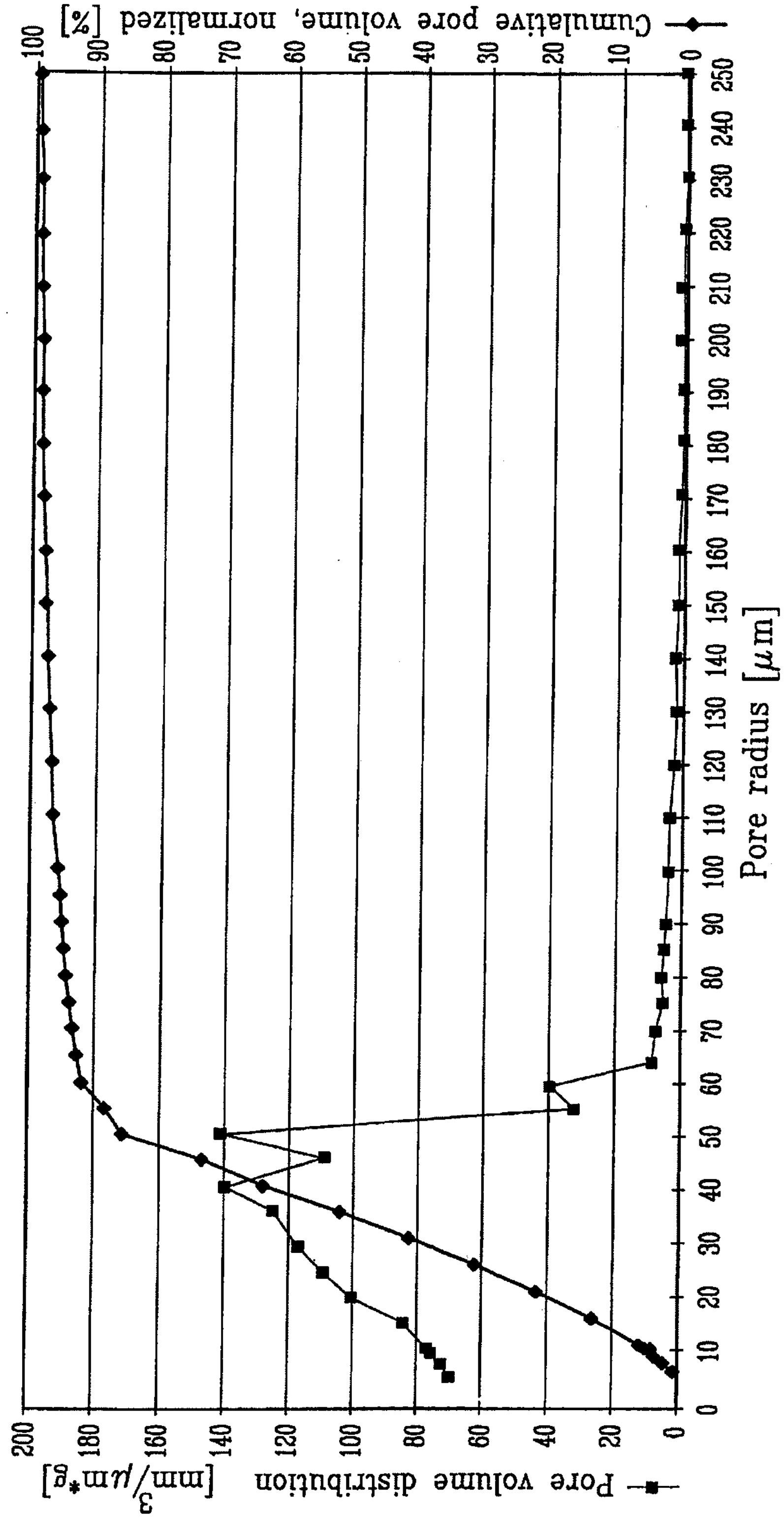

Cumulative pore volume, normalized [%]
100
90
80
70
60
50
40
30
20
10
0
Pore volume distribution [mm³/μm*g]
200
180
160
140
120
100
80
60
40
20
0
Pore radius [μm]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250

FIG. 9

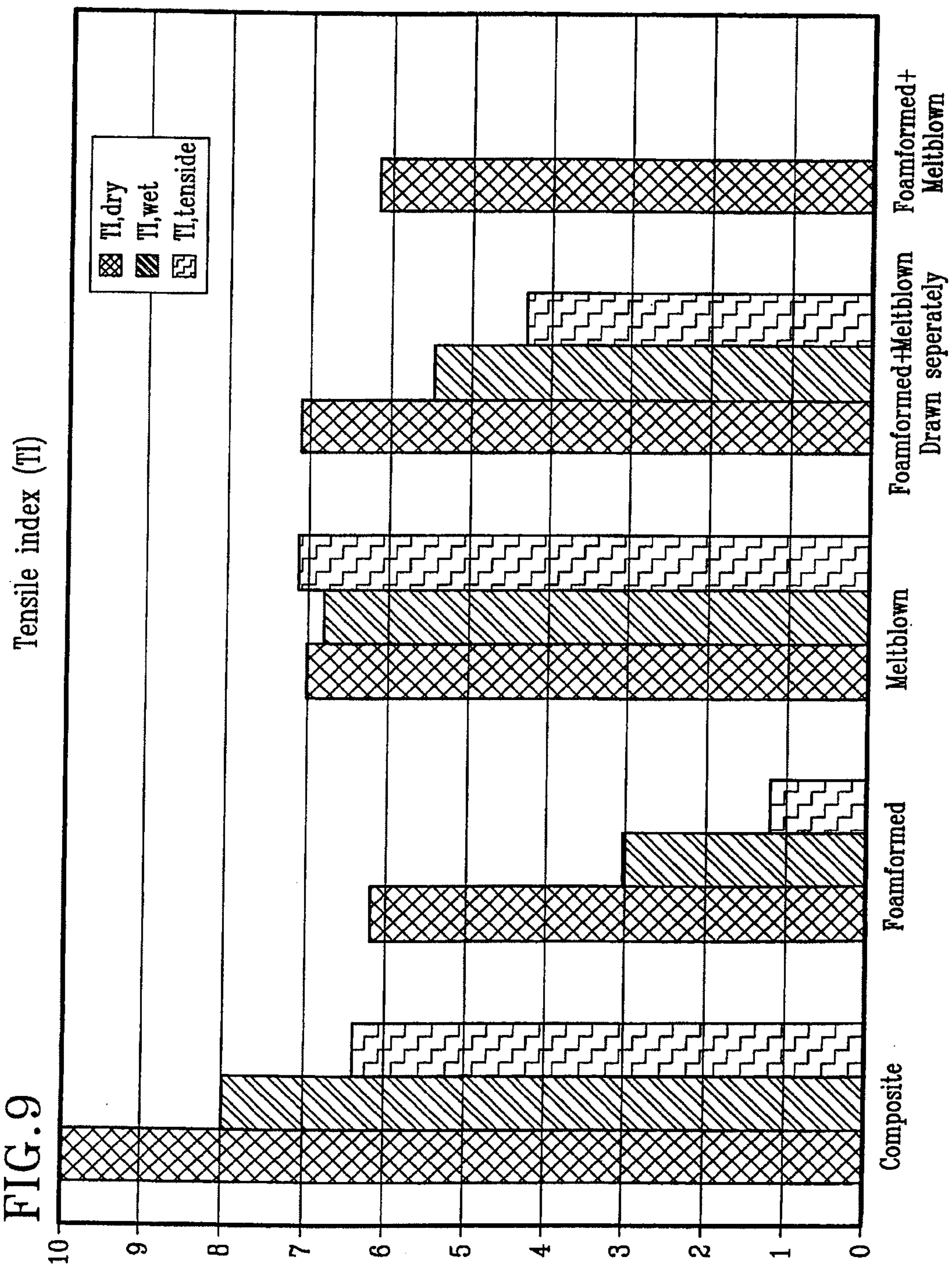

Tensile index (TI)
TI,dry
TI,wet
TI,tenside
0
1
2
3
4
5
6
7
8
9
10
Composite
Foamformed
Meltblown
Foamformed+Meltblown
Drawn seperately
Foamformed+
Meltblown

FIG. 10

METHOD OF PRODUCING A NONWOVEN MATERIAL

BACKGROUND OF THE INVENTION

The present invention refers to a method of producing a nonwoven material by hydroentangling a fiber mixture containing continuous filaments and natural fibers and/or synthetic staple fibers.

Hydroentangling or spunlacing is a technique introduced during the 1970'ies, see e g CA patent no. 841 938. The method involves forming a fiber web which is either drylaid or wetlaid, after which the fibers are entangled by means of very fine water jets under high pressure. Several rows of water jets are directed against the fiber web which is supported by a movable wire. The entangled fiber web is then dried. The fibers that are used in the material can be synthetic or regenerated staple fibers, e g polyester, polyamide, polypropylene, rayon or the like, pulp fibers or mixtures of pulp fibers and staple fibers. Spunlace materials can be produced in high quality to a reasonable cost and have a high absorption capacity. They can e g be used as wiping material for household or industrial use, as disposable materials in medical care and for hygiene purposes etc.

In WO 96/02701 there is disclosed hydroentangling of a foamformed fibrous web. The fibers included in the fibrous web can be pulp fibers and other natural fibers and synthetic fibers.

Through e g EP-B-0 333 211 and EP-B-0 333 228 it is known to hydroentangle a fiber mixture in which one of the fiber components is meltblown fibers. The base material, i e the fibrous material which is exerted to hydroentangling, either consists of at least two preformed fibrous layer where one layer is composed of meltblown fibers or of a "coform material" where an essentially homogeneous mixture of meltblown fibers and other fibers is airlaid on a wire and after that is exerted to hydroentangling.

Through EP-A-0 308 320 it is known to bring together a web of continuous filaments with a wetlaid fibrous material containing pulp fibers and staple fibers and hydroentangle together the separately formed fibrous webs to a laminate. In such a material the fibers of the different fibrous webs will not be integrated with each other since the fibers during the hydroentangling are bonded to each other and only have a very limited mobility.

OBJECT AND MOST IMPORTANT FEATURES OF THE INVENTION

The object of the present invention is to provide a method for producing a hydroentangled nonwoven material of a fibrous mixture of continuous filaments, e g in the form of meltblown and/or spunbond fibers and natural fibers and/or synthetic staple fibers, where there is given a high freedom in the choice of fibers and where the continuous filaments are well integrated with the rest of the fibers. This has according to the invention been obtained by foamforming a fibrous web of natural fibers and/or synthetic staple fibers and hydroentangling together the foamed fiber dispersion with the continuous filaments for forming a composite material where the continuous filaments are well integrated with the rest of the fibers.

Through the foamforming there is achieved an improved mixing of the natural and/or synthetic fibers with the synthetic filaments, said mixing effect is reinforced by the hydroentangling, so that a composite material is obtained in which all fiber types are essentially homogenously mixed with each other. This is among other things shown by the very high strength properties of the material and by a wide pore volume distribution.

DESCRIPTION OF THE DRAWINGS

The invention will below be closer described with reference to some embodiments shown in the accompanying drawings.

FIGS. **1–5** show schematically some different embodiments of devices for producing an hydroentangled nonwoven material according to the invention.

FIGS. **6** and **7** show the pore volume distribution in a reference material in the form of a foamformed spunlace material and of a spunlace matierial consisting only of meltblown fibers.

FIG. **8** shows the pore volume distribution in a composite material according to the invention.

FIG. **9** shows in the form of a staple diagram the tensile strength in dry and wet condition and in a tenside solution for the composite material and for the two base materials included therein.

FIG. **10** is an electron microscope picture of a nonwoven material produced according to the invention.

DESCRIPTION OF SOME EMBODIMENTS

FIG. **1** shows schematically a device for producing a hydroentangled composite material according to the invention. A gas stream of meltblown fibers is formed according to conventional meltblown technique by means of a meltblown equipment **10**, for example of the kind shown in the U.S. Pat. Nos. 3,849,241 or 4,048,364. The method shortly involves that a molten polymer is extruded through a nozzle in very fine streams and converging air streams are directed towards the polymer streams so that they are drawn out into continuous filaments with a very small diameter. The fibers can be microfibers or macrofibers depending on their dimension. Mcrofibers have a diameter of up to 20 μm, but usually are in the interval between 2 and 12 μm in diameter. Macrofibers have a diameter of over 20 μm, e g between 20 and 100 μm.

All thermoplastic polymers can in principle be used for producing meltblown fibers. Examples of useful polymers arer polyolefines, such as polyethylene and polypropylene, polyamides, polyesters and polylactides. Copolymers of these polymers may of course also be used, as well as natural polymers with thermoplastic properties.

Spunbond fibers are produced in a slighty different way by extruding a molten polymer, cool it and stretch it to an appropriate diameter. The fiber diameter is usually above 10 μm, e g between 10 and 100 μm.

The continuous filaments will in the following be described as meltblown fibers, but it is understood that also other types of continuous filaments, e g spunbond fibers, can be used.

According to the embodiment shown in FIG. **1** the meltblown fibers **11** are laid down directly on a wire **12** where they are allowed to form a relatively loose, open web structure in which the fibers are relatively free from each other. This is achieved either by making the distance between the meltblown nozzle and the wire relativley large, so that the filaments are allowed to cool down before they land on the wire **12**, at which their stickiness is reduced. Alternatively cooling of the meltblown fibers before they are laid on the wire is achieved in some other way, e g by means of spraying with liquid. The basis weight of the formed

meltblown layer should be between 2 and 100 g/m^2 and the bulk between 5 and 15 cm^3/g.

A foamformed fibrous web **14** from a headbox **15** is laid on top of the meltblown layer. Foamforming means that a fibrous web is formed from a dispersion of fibers in a foamed liquid containing water and a tenside. The foamforming technique is for example described in GB 1,329,409, U.S. Pat. No. 4,443,297 and in WO 96/02701. A foam-formed fibrous web has a very uniform fiber formation. For a more detailed description of the foamforming technique reference is made to the above mentioned documents. Through the intensive foaming effect there will already at this stage occur a mixing of the meltblown fibers with the foamed fiber dispersion. Air bubbles from the intensive turbulent foam that leaves the headbox **15** will penetrate down between and push apart the movable meltblown fibers, so that the somewhat coarser foam-formed fibers will be integrated with the meltblown fibers. Thus after this step there will mainly be an integrated fibrous web and no longer layers of different fibrous webs.

Fibers of many different kinds and in different mixing proportions can be used for making the foamformed fibrous web. Thus there can be used pulp fibers or mixtures of pulp fibers and synthetic fibers, e g polyester, polypropylene, rayon, lyocell etc. As an alternative to synthetic fibers natural fibers with a long fiber length can be used, e g above 12 mm, such as seed hair fibers, e g cotton, kapok and milkweed; leaf fibers e g sisal, abaca, pineapple, New Zealand hamp, or bast fibers, e g. flax, hemp, ramie, jute, kenaf. Varying fiber lengths can be used and by foamforming technique longer fibers can be used than what is possible with conventional wetlaying of fiber webs. Long fibers, ca. 18–30 mm, is an advantage in hydroentangling, since they increase the strength of the material in dry as well as in wet condition. A further advantage with foamforming is that is is possible to produce materials with a lower basis weight than is possible with wetlaying. As a substitute for pulp fibers other natural fibers with a short fiber length can be used, e g esparto grass, phalaris arundinacea and straw from crop seed.

The foam is sucked through the wire **12** and down through the web of meltblown fibers laid on the wire, by means of suction boxes (not shown) arranged under the wire. The integrated fibrous web of meltblown fibers and other fibers is hydroentangled while it is still supported by the wire **12** and herewith forms a composite material **24**. Possibly the fibrous web can before hydroentangling be transferred to a special entangling wire, which possibly can be patterned in order to form a patterned nonwoven material. The entangling station **16** can include several rows of nozzles from which very fine water jets under very high pressure are directed against the fibrous web to provide an entangling of the fibers.

For a further description of the hydroentangling—or as it also is called the spunlace technique reference is made to e g CA patent 841,938.

The meltblown fibers will thus already before the hydroentangling be mixed with and integrated with the fibers in the foamformed fibrous web due to the foaming effect. In the subsequent hydroentangling the different fiber types will be entangled and a composite material is obtained in which all fiber types are substantially homogeneously mixed and integrated with each other. The fine mobile meltblown fibers are easily twisted around and entangled with the other fibers which gives a material with a very high strength. The energy supply needed for the hydroentangling is relatively low, i e the material is easy to entangle. The energy supply at the hydroentangling is appropriately in the interval 50–300 kWh/ton.

The embodiment shown in FIG. **2** differs from the former by the fact that a preformed tissue layer or spunlace material **17**, i e a hydroentangled nonwoven material, is used, on which the meltblown fibers **11** are laid, after which the foamformed fibrous web **15** is laid on top of the meltblown fibers. The three fibrous layers are mixed due to the foaming effect and are hydroentangled in the entangling station **15** to form a composite material **24**.

According to the embodiment shown in FIG. **3** a first foamformed fibrous web **18** is laid on the wire **12** from a first headbox **19**, on top of the fibrous web the meltblown fibers **11** are laid and finally a second foamformed fibrous web **20** from a second headbox **21**. The fibrous web **18**, **11** and **20** formed on top of each other are mixed due to the foaming effect and are then hydroentangled while they are still supported by the wire **12**. It is of course also possible only to have the first foamformed fibrous web **18** and the meltblown fibers **11** and hydroentangle together these two layers.

The embodiment according to FIG. **4** differs from the previous by the fact that the meltblown fibers **11** are laid on a separate wire **22** and the preformed meltblown web **23** is fed between the two foam forming stations **18** and **20**. It is of course possible to use a correspondingly preformed meltblown web **23** also in the devices shown in FIGS. **1** and **2**, where foamforming is made only from the upper side of the meltblown web **23**.

According to the embodiment shown in FIG. **5** a layer of meltblown fibers **11** are laid directly on a first wire **12*a***, after which a first foamformed fibrous web **18** is laid on top of the meltblown layer. The fibrous web is then transferred to a second wire **12*b*** and turned over after which a second foamformed fibrous web **20** is laid on the "meltblown side" from the opposide side thereof. The fibrous web is transferred to an entangling wire **12*c*** and is hydroentangled. For the sake of simplicity the fibrous web in FIG. **5** is not shown along the transporting portions between the forming—and entangling stations.

According to a further alternative embodiment (not shown) the meltblown fibers are fed directly into the foamed fiber dispersion, before or in connection to the formation thereof. The admixture of the meltblown fibers can for example be made in the headbox.

The hydroentangling is preferably made in a known manner from both sides of the fibrous material at which a more homogeneous equilateral material is obtained.

After the hydroentangling the material **24** is dried and wound up. The material is then converted in a known way to a suitable format and is packed.

EXAMPLE 1

A foamformed fiber dispersion containing a mixture of 50% pulp fibers of chemical kraft pulp and 50% polyester fibers (1.7 dtex, 19 mm), was laid on a web of meltblown fibers (polyester, 5–8 μm) with a basis weight of 42.8 g/m^2 and hydroentangled together therewith, at which a composite material with a basis weight of 85.9 g/m^2 was obtained. The energy supply at the hydroentangling was 78 kWh/ton. The material was hydroentangled from both sides. The tensile strength in dry and wet condition, the elongation and the absorption capacity of the material were measured and the results are shown in the table below. As reference materials a foamformed fibrous web (Ref. **1**) and a meltblown web (Ref. **2**) corresponding to those used for pro-

ducing the composite material were hydroentanled. The measurement test results for these reference materials both separate and laid together to a double-layer material are presented in table 1 below.

TABLE 1

	Composite	Ref. 1	Ref. 2	Ref. 1 + 2 drawn separately	Ref. 1 + 2 drawn together
Basis weight (g/m^2)	85.9	43.6	42.8	86.4	86.4
Thickness (μm)	564	373	372	745	745
Bulk (cm^3/g)	6.6	8.6	8.7	8.6	8.6
Tensile stiffness index	102.5	22.2	8.8	—	—
Tensile strength dry, MD (N/m)	1155	540	282	822	644
Tensile strength dry, CD (N/m)	643	136	318	454	438
Tensile index, dry, (Nm/g)	10	6.2	7	7.1	6.1
Elongation MD, %	40	26	75	—	—
Elongation CD, %	68	116	103	—	—
$\sqrt{MD \cdot CD}$	52	55	88		
Work to rupture MD (J/m^2)	375	163	175	—	—
Work to rupture CD (J/m^2)	341	99	256	—	—
Rupture index (J/g)	4.2	2.9	4.9	—	—
Tensile strength wet, MD, (N/m)	878	372	299	671	—
Tensile strength wet, CD, (N/m)	538	45	285	330	—
Tensile index wet (Nm/g)	8	3	6.8	5.4	—
Tensile strength tenside, MD, (N/m)	605	116	281	397	—
Tensile strength tenside, CD, (N/m)	503	22	326	348	—
Tensile index tenside (Nm/g)	6.4	1.2	7.1	4.3	—
Energy supply (kWh/ton)	78	61	77	—	—
Total absorption (g/g)	4.5	6.1	0.2	—	—

As is seen from the above measurement results the tensile strength in dry as well as in wet condition and in tenside solution was considerably higher for the composite material than for the combined reference materials. This indicates that there is a good mixture between the meltblown fibers and the other fibers, which results in an increase of the material strength.

In FIG. **9** there is shown in the form of staple diagram the tensile index in dry and wet condition and in tenside solution for the different materials.

The total absorption of the composite material is almost as good for the reference material 1, i e a corresponding spunlace material without admixture of meltblown fibers. On the other hand the absorption was considerably higher than for the reference material 2, i e a pure meltblown material.

In FIG. **7** there is shown the pore volume distribution of the foamformed reference material, Ref. 1, in $mm^3/\mu m.g$, and the normalized cumulative pore volume in %. It can be seen that the main part of the pores in the material are in the interval 60–70 μm. In FIG. **7** there is shown the corresponding pore volume distribution for the meltblown material, Ref. 2. The main part of the pores in this material are below 50 μm. From FIG. **8**, which shows the pore volume distribution of the composite material according to above, it can be seen that the pore volume distribution for this material is

considerably broader than for the two reference materials. This indicates that there is an effective mixture of fibers in the composite material. A broad pore volume distribution in a fibrous structure improves the absorption—and liquid distribution properties of the material and is thus advantageous.

It can also be seen from the electron microscope picture according to FIG. **10**, which shows the composite material produced according to the above described example, that the fibers are well integrated and mixed with each other.

EXAMPLE 2

A number of hydroentangled materials with different fiber compositions were produced and tested with respect to tensile strength in wet and in dry condition, work to rupture and elongation.

Material 1: A foamformed fiber dispersion containing 100% pulp fibers of chemical kraft pulp, basis weight 20 g/m^2, was laid on both sides of a very slightly thermobonded, slightly compressed layer of spunbond fibers of polypropylene (PP) 1.21 dtex, basis weight 40 g/m^2, and was hydroentangled together therewith. The tensile strength of the PP-fibers was 20 cN/tex, the E-modulus was 201 cN/tex and the elongation was 160%. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 57 kWh/ton.

Material 2: A layer of tissue paper of chemical pulp fibers was laid on both sides of a spunbond material, the same as in material A above. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 55 kWh/ton.

Material 3: A foamformed fiber dispersion containing 100% pulp fibers of chemical kraft pulp, basis weight 20 g/m^2, was laid on both sides of a very slightly thermobonded, slightly compressed layer of spunbond fibers of polyester (PET) 1.45 dtex, basis weight 40 g/m^2, and was hydroentangled together therewith. The tensile strength of the PET-fibers was 22 cN/tex, the E-modulus was 235 cN/tex and the elongation 76%. The materialet was hydroentangled from both sides. The energy supply at the hydroentangling was 59 kWh/ton.

Material 4: A layer of tissue paper of pulp fibers (85% chemical pulp and 15% CTMP), with the basis weight 26 g/m^2 was laid on both sides of a spunbond material, the same as in material A above. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 57 kWh/ton.

Material 5: A wetlaid fibrous web containing 50% polyester (PET) fibers (1.7 dtex, 19 mm) and 50% pulp fibers of chemical pulp was hydroentangled with an energy supply of 71 kWh/ton. The basis weight of the material was 87 g/m^2. The tensile strength of the PET-fibers was 55 cN/tex, the E-modulus was 284 cN/tex and the elongation was 34%.

Material 6: The same as for material 5 above but hydroentangled with a considerably higher energy supply, 301 kWh/ton. The basis weight of the material was 82.6 g/m^2.

Materials 1 and 3 are composite materials according to the present invention while materials 2 and 4 are laminate materials outside the invention and shall be seen as reference materials. Materials 5 and 6 are conventional hydroentangled materials and should also be seen as references. The energy supply at the hydroentangling of material 5 was of the same order of magnitude as was used for the hydroentangling of materials 1–4, while the energy supply at the hydroentangling of material 6 was considerably higher.

The results of the measurements are shown in table 2 below.

TABLE 2

	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Bases weight (g/m^2)	86.7	93.3	83.6	90.7	87	82.6
Thickness 2kPa (μm)	520	498	415	470	550	463
Bulk 2kPa (cm^3/g)	6.0	5.3	5.0	5.2	6.3	5.6
Tensile stiffness MD (N/m)	18310	18290	20740	20690	10340	12590
Tensile stiffness CD (N/m)	3250	3531	6546	4688	1756	1709
Tensile stiffness index (Nm/g)	89	86	139	109	49	56.2
Tensile strength dry MD, (N/m)	4024	3746	4192	3893	2885	4674
Tensile strength dry CD, (N/m)	1785	1460	2255	1619	998	1476
Tensile index dry (Nm/g)	31	25	37	28	19.5	31.8
Elongation MD (%)	73	84	80	83	32	34.4
Elongation CD (%)	129	123	100	98	90	87.6
Elongation $\sqrt{MDCD}$ (%)	97	102	89	90	54	55
Work to rupture MD (J/m^2)	2152	2618	2318	2370	600	906
Work to rupture CD (J/m^2)	1444	1216	1425	1084	484	695
Work to rupture index (J/g)	20.3	19.1	21.7	17.7	6.2	9.6
Tensile strength MD, wet (N/m)	4401	2603	4028	3574	2360	4275
Tensile strength CD, wet (N/m)	1849	1850	1940	1365	729	1363
Tensile index wet (Nm/g)	32.9	23.5	33.4	24.4	15.1	29.2
Relative strength water (%)	106	94	91	88	77	92
Tensile strength MD tenside (N/m)	3987	1489	3554	2879	874	3258
Tensile strength CD tenside (N/m)	1729	1083	1684	1214	234	985
Tensile index tenside (Nm/g)	30.3	13.6	29.3	20.6	5.2	21.7
Relative strength tenside (%)	98	54	80	74	27	68

The results show higher strength values for the composite materials according to the invention (materials 1 and 3) both compared to the corresponding laminate materials (materials 2 and 4) and compared to the wetlaid reference material (material 5) which had been entangled with an equivalent energy supply. Especially the tensile strength values as well wet, dry as in tenside are considerably higher for the composite materials according to the invention in comparison with the reference materials. The high strength values verifies that one has a composite material with very well integrated fibers.

For material 6 which had been entangled with a considerably higher energy supply (about 5 times higher) than for the composite materials the tensile strength in dry condition is on the same level as for the composite materials. The relative wet- and tenside strength as well as the work to rupture index are still markedly lower than for the composite materials.

As a further comparison two layers of the spunbond materials used in the above tests were hydroentangled. These material are denoted as materials 6 and 7.

Material 7: Two layers PP-spunbond, 1.21 dtex, each of the basis weight 40 g/m^2, were hydroentangled with an energy supply of 66 kWh/ton.

Material 8: Two layers PET-spunbond, 1.45 dtex, each of the basis weight 40 g/m^2, were hydroentangled with an energy supply of 65 kWh/ton.

The measurement results obtained with these materials are shown in table 3 below.

TABLE 3

	Material 7	Material 8
Basis weight (g/m^2)	78.2	78.4
Thickness 2 kpa (μm)	865	762
Bulk 2kPa (cm^3/g)	11.1	9.7
Tensile stiffness MD (N/m)	8314	9792
Tensile stiffness CD (N/m)	507	897
Tensile stiffness index (Nm/g)	26	38
Tensile strength MD dry (N/m)	642	798
Tensile strength CD dry (N/m)	183	558
Tensile index dry (Nm/g)	4	9
Elongation MD (%)	9	32
Elongation CD (%)	112	105
Elongation $\sqrt{MDCD}$ (%)	32	58
Work to rupture MD (J/m^2)	313	604
Work to rupture CD (J/m^2)	253	508
Work to rupture index (J/g)	3.6	7.1
Tensile strength MD wet (N/m)	210	965
Tensile strength CD wet (N/m)	217	659
Tensile index wet (Nm/g)	2.7	10.2
Relative strength wet (%)	62	120
Tensile strength MD tenside (N/m)	840	713
Tensile strength CD tenside (N/m)	178	292
Tensile index tenside (Nm/g)	4.9	5.8
Relative strength tenside (%)	113	68

As is seen these material have considerably lower strength values in all aspects as compared to the composite materials according to the invention.

The composite material according to the invention has very high strength values at a very low energy supply at the entangling. The reason for this is the homogeneous fiber mixture that has been created, in which the synthetic fibers and the pulp fibers cooperate in the fibrous network so that unusually favourable synergistic effects are achieved. The high values for elongation and work to rupture verifies that there is a composite material with very well integrated fibers and that they cooperate so that the material can take up very large deformations without breaking.

The invention is of course not limited to the embodiments shown in the drawings and described above but can be modified within the scope of the claims.

What is claimed is:

1. A method of producing a nonwoven material by hydroentangling a fiber mixture of continuous filaments with

natural fibers and/or synthetic staple fibers, the method comprising the steps of:

foamforming a fibrous web of the natural fibers and/or the synthetic staple fibers,

forming a layer of continuous filaments, and

hydroentangling together the foamed fiber dispersion with the continuous filaments to form a composite material where the continuous filaments are well integrated with the rest of the fibers.

2. The method as claimed in claim **1**, wherein the foam forming occurs directly on the layer of continuous filaments and further comprising the step of draining the foam formed fibrous web through the filament layer.

3. The method as claimed in claim **1**, wherein the layer of continuous filaments is laid directly on top of the fibrous web followed by draining of said fibrous web.

4. The method as claimed in claim **1**, wherein the layer of continuous filaments is laid between two foamed fiber dispersions followed by draining said foamed fiber dispersions.

5. The method as claimed in claim **1**, wherein the continuous filaments are laid on a preformed layer of tissue or nonwoven.

6. The method as claimed in claim **1**, wherein the continuous filaments are fed directly into a foamed fiber suspension before or in connection with formation for forming said foamed fiber dispersion.

7. The method as claimed in claim **1**, wherein pulp fibers are present in the foamed fiber dispersion.

8. The method as claimed in claim **1**, wherein the continuous filaments are supplied in the form of a relatively loose, open weblike fibrous structure in which the fibers are substantially free from each other, so that they easily can be released from each other and be integrated with the fibers in the foamed fiber dispersion.

9. The method as claimed in claim **1**, wherein the continuous filaments are meltblown fibers and/or spunbond fibers.

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(54) PROCESS FOR PRODUCING A NONWOVEN WEB

(57) **Abstract:**

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This invention relates to improved textile-like nonwoven fabrics made from paper fibers and to a process for their preparation using liquid streams.

Much effort has been expended in an effort to make nonwoven fabrics containing a major proportion of paper fibers. Modified papermaking techniques, using blends of short fibers, reinforcing webs, creping, etc., have afforded some improvement but the products are paper-like rather than cloth-like and are characterized by a lack of durability in use, low abrasion resistance and a high stiffness or lack of drape. Similarly, dry formation of such structures by either air deposition or carding systems followed by bonding by suitable solvent or thermally activated binders provide structures having poor drape characteristics.

In accordance with the present invention, it has been found that nonwoven structures produced by papermaking processes can be treated with high pressure jet streams of water to impart greater toughness, flexibility and extensibility, and a surprising resistance to abrasion and surface distortion. These improvements are obtained without use of size or adhesives. Fabrics having a high degree of absorbency, which may be much greater than the untreated starting paper, in combination with desirable textile-like drape, soft hand, surface durability and optical covering power are provided. The products may have a felt-like appearance or may simulate the appearance of a woven fabric.

Embodiments of the invention which consist essentially of paper fibers have a highly entangled fiber structure characterized by a considerable proportion of fiber segments aligned transversely to the plane of the fabric. The relative fiber positions are evaluated by a "90/0 ratio" optical method, described subsequently, and are quite different from the substantially planar fiber

positions previously found in paper. This entanglement provides a lower density, which is softer and more absorbent than conventional paper. These embodiments are characterized by a 90/0 ratio of at least 0.33, a density of less than 0.3 gm./cc., a strip tensile strength of at least 0.7 lb./in. per oz./yd.^{2}, and an elongation-at-break of at least 10% in all directions. Preferred products have strengths of 1.0 lb./in. per oz./yd.^{2} or better. Preferably the elongation-at-break is at least 20%.

Other embodiments contain up to 25% textile staple fibers uniformly distributed through the paper fibers. Stronger products can be provided in this way.

The staple fibers are preferably less than 0.75 inch in length (1.9 cm.) so that the fiber mixture can be processed into paper from a slurry on papermaking equipment. Mixtures containing longer staple fibers can be dry-processed into sheet form by random air deposition methods and then treated with the high pressure jet streams of water.

Any of the above embodiments can be assembled with one or more layers of a different type, e.g., a layer of textile fibers or polyurethane foam, and the assembly traversed with high pressure jet streams of liquid to unite the layers into a laminated structure. By assembling an untreated paper layer on top of the second layer, the paper layer can be treated and united with the second layer in a single operation. A preferred embodiment is prepared by depositing textile fibers to form a layer of randomly oriented fibers, entangling the fibers in the layer by treatment with high pressure jet streams to form a fabric which can readily be used in the next step, assembling the fabric with a layer of paper fibers, and traversing the combination with high pressure jet streams of water to form a laminated fabric characterized by a 90/0 ratio of at least 0.33, a density of less than 0.3

gm./cc., and a strip tensile strength of 1.0 (preferably at least 2.0) lb./in. per oz./yd.^{2}. In this embodiment, the paper fibers provide absorbency and resistance to abrasion, the textile fibers provide improved wet and dry strength, and the combination has desirable drape, softness and covering power.

In forming the laminated embodiments, the layer of textile fibers may consist of any arrangement of the fibers such as woven or knitted fabrics, nonwoven fabrics or loose webs, mats or batts. Non-woven fabrics of staple or continuous filaments may be bonded by resins, fusion, entanglement or needle punching. Loose webs having fibers disposed in random relationship to one another or in any degree of alignment may be used. Combinations of these arrays may be desirable for certain uses. By "textile fibers" is meant fibers and plexifilaments of about 0.5 to 10 denier per filament having a length of at least 6 millimeters. The fibers may be natural or synthetically produced, straight or crimped, or possess a latent ability to elongate, crimp or shrink when heated or given other aftertreatment. In the products of this invention there is a high degree of entangling of the paper fibers with the textile fiber layer, so that the layers are securely held together and perform as a unitary structure in use.

The process of this invention will be better understood from the drawing wherein,

Figure 1 is a schematic side elevational view of one form of apparatus for continuous production of embodiments discussed above, and

Figure 2 is an exploded isometric view of a jet manifold for use in the above apparatus.

The production of fabric with the above apparatus can be summarized as an improvement in the conventional papermaking process of preparing a stock suspension of fibers

in water, continuously screening fibers from the stock to form a wet mat, mechanically removing water from the mat to form a sheet, and drying the sheet; wherein the improvement comprises supporting the sheet on an apertured backing member such as a fine mesh screen, jetting water supplied at pressures of 200 to 2000 pounds per square inch (psi.) to form streams having an energy flux of at least 2300 foot-poundals/in.^{2} second and a diameter of 3 to 10 mils at the treatment distance, traversing the supported sheet with the streams until a stream energy of 0.05 to 2.0 horsepower-hours per pound of product has been applied, optionally continuing the treatment on a relatively coarse apertured patterning member until a stream energy of 0.05 to 1.0 horsepower-hour per pound of fabric has been applied to form a patterned nonwoven fabric, and drying the product.

The high energy flux streams are preferably formed by jetting water, supplied at a pressure of 750 to 1500 psi., from manifolds having orifices of 3 to 5 mils in diameter arranged in a straight line at right angles to the direction of travel of the sheet being treated. The orifices may be spaced 10 or more per inch, and preferably about 30 to 50 per inch. The treatment with the high energy flux streams can be performed at any time after the sheet has sufficient strength to be transferred to a supporting surface for treatment, but is most economically performed prior to the dryers. When forming a laminated fabric, a preformed layer of textile fibers can be fed continuously under the sheet at any convenient location prior to treatment of the assembly with high energy flux streams.

Referring to Figure 1, the portion designated "Fourdrinier" illustrates the basic features of the wet end of a conventional papermaking machine. A suspension of paper fibers is introduced into stuff box 1, from where it flows at a properly controlled rate into mixing box 2.

Water is added at inlet 3 to provide a stock of uniform consistency suitable for the grade of paper to be produced. The stock flows through section 4, where it is screened to remove foreign particles, and into a headbox 5 designed to insure smooth flow and to maintain a uniform mixture. The stock exits from the headbox as a fluid sheet of uniform thickness through slice 6. The stock is received on Fourdrinier wire 7, an endless belt of fine mesh wire screen, which travels continuously over breast roll 8 beneath the slice 6. The wire 7 passes over table rolls 9, around driven couch roll 10 and back to the breast roll. Dandy roll 11 is used to smooth the top surface of the sheet. Suction boxes 12 assist in draining water from the stock to form a wet paper mat. Suction is also applied in the couch roll to lower the water content of the mat to around 80% so the mat will have sufficient strength for removal from the wire.

The wet paper mat is transferred to felt 13 and is passed between press rolls 14 and 15 to remove additional water from the mat. The water is carried away by the felt, which is guided around rolls 16. More water is removed in a second similar press-section, comprising press rolls 17 and 18, felt 19 and felt rolls 20. The press rolls reduce the water content and form a consolidated paper sheet of adequate strength for the jet treating step of this invention.

The portion of Figure 1 designated "Jet Treating" indicates basic features of an apparatus for treating the paper sheet with high pressure streams of water. Two treatment drums 21 and 22 are shown. These have apertured cylindrical surfaces for supporting the sheet. Suction means similar to a suction couch roll is preferably provided for holding the sheet in place and for removing water during treatment. The optional use of a top screen during part of

the treatment is described subsequently but is not shown in order to keep the drawing simple. Supporting felts may also be desirable but are not shown for purposes of clarity. The cylindrical surface of drum 21 may be a suitably supported, fine mesh wire screen. The surface of drum 22 may be the same or may be a coarse screen for imparting a pattern to the paper sheet.

The paper sheet 23 travels from the presses over rolls 24 and is guided onto the surface of drum 21 by roll 25. The drum rotates clockwise and carries the sheet under a plurality of jet-treatment manifolds 26. Only three are shown for simplicity, but a much larger number may be required for high speed operation. The treated sheet passes from drum 21 over a series of guide rolls 27 to the drum 22. This drum rotates counter-clockwise and the sheet is fed onto it so that the treated face is next to the cylindrical surface of the drum. The sheet is carried beneath a plurality of jet-treatment manifolds 28 to treat the face of the sheet opposite to that previously treated. The treated sheet leaves the drum at guide roll 29, passes to press rolls 30 and 31, and is then guided by a series of rolls 32 to the dryers.

The dryers are of the type conventionally used on the dry end of a papermaking machine. The drums 33 are steam-heated and arranged alternately up and down. The treated sheet 34 follows a serpentine path passing over the upper drums and under the lower drums. Blanket felts 35 and 36 hold the treated sheet tightly against the drums and increase the effectiveness of the dryers. After drying, the sheet proceeds to a conventional windup 37.

Figure 2 is a perspective view of a portion of one of the jet-treating manifolds 26 or 28 with the parts separated for clarity. Along the central axis of flat metal strip 40 are equally-spaced jet orifices 41. Above this jet strip is a perforated filter plate 42 which has the same outer dimensions as the jet strip but is curved upward along the central axis so that the plate is spaced away from the jet orifices. The plate is perforated with holes 43 which are no larger than the jet orifices so that particles of foreign matter are caught before they can plug the jet orifices. The holes are uniformly arranged along the curved portion of the plate to provide an even flow of liquid to the different jet orifices. A sufficient number of holes to provide about 3.5% open area produces an even flow without excessive pressure drop through the filter plate.

The manifold body 44 has an undercut portion 45, for receiving the filter plate and jet strip, and has a slot 46 which forms a liquid chamber above the filter plate. Fitting 47 connects to the supply of high pressure liquid. A heavy retainer plate 48 is secured to the manifold body by bolts 49 to hold the filter plate and jet strip in place in undercut portion 45 with a liquid-tight seal. A slit 50 extends along the central axis of the retainer plate to expose the jet orifices.

Equipment for supplying high pressure liquid to the manifold is indicated in Figure 1. Used treating liquid is collected in tank 51 and is withdrawn through drain 52. The liquid passes through filter 53 to remove foreign matter and continues through pipe 54 to pump 55. A multiple-piston, positive-displacement pump powered by

an electric motor 56 is preferred, although other types of pumps can be used. A pulsation dampener 57 is provided in high pressure pump line 58. The high pressure liquid flows from the dampener to a second filter 59 designed to remove any remaining particles of material large enough to plug the jet orifices. A pleated woven screen which will remove any particles larger than 25 microns in size is preferred. The filtered liquid then flows into feed manifold 60 which supplies the jet manifolds. Conventional pressure control and pressure relief valves should be provided for regulating the pressure of individual jet manifolds with safety.

The products of this invention can be prepared from any of the fibers which have previously been used in papermaking. The term "paper fibers" is used herein with reference to fibers having an average length of up to about 4 millimeters, and includes wood pulp, cotton linters and other natural cellulosic fibers, regenerated cellulose, chemically modified cellulosic fibers, synthetic polymer fibrids and very short plexifilament fibers.

For obtaining maximum strength a long fiber wood pulp species (such as kraft), which has been highly refined, is preferred. Excessive beating during refining reduces the maximum tear strength.

For attaining maximum drape and conformability a short fiber pulp (such as hard wood pulp) should be used. It may be desirable for some products to use a blend of several types of wood pulp to optimize physical and aesthetic properties.

Due to the nature of the cellulosic fibers, a varied degree of fibrillation of these fibers occurs during

the hydraulic treatment apart from any previous pulp treatments or linter refining. Such fibrillation further increases the response to continued hydraulic treatment and contributes to such properties as tensile strength and covering power.

Preferably a finely apertured backing member is used as a support during the jet treatment. It may consist of a perforated plate, sheet, woven screen, honeycomb or the like made of any suitable material which is not susceptible to attack by the fluid streams. Plain woven wire screens have been found to be satisfactory. Preferably these will contain from 60 to 200 mesh per inch (per 2.54 cm.). The use of coarser screens affords an increased loss of the small paper fibers and increased problems in reusing the spent wash liquid.

Unless stated to the contrary in the examples, the orifices remain stationary. This produces a fine pattern of very shallow grooves and furrows on the top of the composite web facing the orifices. This effect is reduced when the orifices are oscillated or when the spacing between orifices is decreased.

It may be desirable to reverse the composite web on the support screen so that the original top layer of paper-making fibers faces the screen for a finishing step. This is termed "flipping". A relatively coarse screen can be used for such a finishing step when the fiber structure has been given sufficient integrity in the first treatment. A patterned structure resembling a conventional woven fabric can be produced in this manner. A suitable patterning member may be any screen, perforated or grooved plate which by reason of its apertures and/or surface contours influences

the movement of fibers into a pattern in response to the fluid streams. Included are screens of about 10 to about 30 mesh per inch and perforated plates having less than 250 openings per square inch. The patterning member may have a planar or nonplanar surface or a combination of the two types.

In order to obtain the products of the present invention, the paper fibers must be treated with streams of a non-compressible fluid at a sufficiently high energy flux and for a sufficient amount of treatment to produce a highly entangled fiber structure. The energy flux of a stream in foot-poundals/in.^{2} second is 77 PG/A, where:

P = the liquid pressure in the manifold in psi.,

G = the volumetric flow of the stream in cu.ft./minute, and

A = the cross-sectional area of the stream (in.^{2}) just prior to impact against the web being treated.

The cross-sectional area (A) can be estimated from photographs of the stream with the web removed, or it can be measured with micrometer probes. The energy flux will be satisfactory when P is from 200 to 2000 psi., the orifice diameter of the stream is from 2 to 7 mils and the diameter of the stream is from 3 to 10 mils just prior to impact with the web. The orifices used in the subsequent examples produce streams having over one million energy flux at the pressures shown.

The amount of treatment must be sufficient and is measured by the energy expended per pound of treated product. The energy (E_1) expended during one passage under a manifold in the preparation of a given nonwoven

fabric, in horsepower-hours per pound of fabric, may be calculated from the formula:

$$E_1 = 0.125\ (YPG/sb)$$

where: Y = number of orifices per linear inch of manifold,
P = pressure of liquid in the manifold in psig.,
G = volumetric flow in cu.ft./min./orifice,
s = speed of passage of the web under the streams, in ft./min., and
b = the weight of the fabric produced, in oz./yd.^{2}.

The total amount of energy expended in treating the web is the sum of the individual energy values for each pass under each manifold. Six manifolds are shown in Figure 1 but a much larger number will normally be used in high speed operation. From the formula it will be seen that increasing the speed of passage under a manifold decreases the energy (E_1) by a proportional amount. The total energy expended per pound of product can be increased by using more manifolds to offset the decrease in energy per manifold. The products of this invention are made by the use of a total energy ranging from 0.05 to about 2 HP-hrs./lb. (0.07 to 2.8 Calorie/gram).

The fabrics prepared in accordance with the present invention are stable, coherent, strong and ready for fabric use. If desired, they may be dyed, printed, heat-treated, or otherwise subjected to conventional fabric processing. Thus, for example, they may be treated with resins, binders, sizes, finishes and the like, surface-coated and/or pressed, embossed, or laminated with other materials, such as foils, films or the like.

The products of the present invention have many applications. Thus, they may be employed in the same uses.

as are conventional woven or knitted fabrics. Typical applications include apparel, linings, home furnishings, towels, upholstery and other decorative materials, padding and/or insulating materials, covering materials and the like. They may be laminated to similar sheets or to different materials.

Tests for Evaluating Physical Properties

In the examples, the tensile properties are measured on an Instron tester at 70°F. and 65% relative humidity. Strip tensile strength is determined for a sample 0.5-inch wide, using a 2-inch sample length and elongating at 50% per minute and reported to the nearest 0.1 unit. The 5% secant modulus (termed "modulus") is determined by A.S.T.M. Standards E6-61, part 10, page 1836 and reported as the nearest whole number. Opacity is determined by T.A.P.P.I. Test T425M-60. Density is calculated from thickness measured with Ames thickness gauges, using a pressure of 4.3 psi. (300 g./cm.^{2}) and the fabric weight.

Abrasion resistance is determined using the Tester of the Custom Scientific Co. of Kearney, N.J. (Model CS-149-005) in which a horizontal Silicon Carbide disc (No. 7K disc) rotates on a vertical axis at about 1 revolution/second. A fabric sample is mounted over a resilient backing on a disc parallel to the abrasive disc and attached to a freely rotating vertical shaft that is about one inch off center from the shaft of the abrasive disc. The sample holder is loaded to a total weight of 1000 g. which presses a 1.25-inch diameter portion of the fabric against the abrasive disc. The test is run until failure, by a hole formation, and the time in minutes reported as "abrasion resistance". At 5 minute intervals

during the test, pills or loose debris are blown off the disc so that such material will not ride under the abrading surface and interfere with the test. Unless otherwise stated the results are given for the paper-making fiber face of the product.

The products of this invention possess a soft drape characteristic of woven fabrics. One measure of this is a normalized-for-weight drape flex value of no more than the value of 3.0 (fabric weight/2.0)$^{2/3}$. These values are 2.5 and 3.9 for fabric weights of 1.5 and 3.0 oz./yd.^{2} as compared to values of 4.1 and 4.8 for paper towels and reinforced paper products having these respective weights. Drape flex or bending length is determined by using a sample 1 inch wide and 6 inches long and moving it slowly in a direction parallel to its long dimension so that its end projects from the edge of a horizontal surface. The length of the overhang is measured when the tip of the sample is depressed under its own weight to the point where the line joining the tip to the edge of the platform makes an angle of 41.5° with the horizontal. One-half of this length is the bending length of the specimen, reported in centimeters.

Evaluation of Relative Fiber Positions

The relative fiber positions in papers or fabrics are evaluated by passing light through microtomed sections of these materials. First, a sample of the fabric or paper is embedded in a clear plastic of index of refraction at 6328 Å differing by at least 0.01 from the index of refraction of the fibers in the sample. An axis is fixed arbitrarily on the sample face and a second axis 90° to the

first is then drawn. Sixty consecutive cross-sections are then cut along each axis. The sections are 30 microns thick, 4 mm. wide and 10 mm. long. Out of each group of sixty, the first and every sixth section thereafter are kept and the remainder discarded. The ten retained are glued between two glass slides with the same plastic in which the samples are embedded.

The scanning apparatus consists of:

(1) a source of a collimated, circularly polarized beam of 6328 Å wave length light which is used to illuminate a .8 x 6 mm. area of sample section. A typical source is a helium-neon laser operating in the TEM $_{oo}$ mode, equipped with a quarter-wave plate. The more uniform the light intensity over the .8 x 6 mm. area, the more accurately the relative length can be measured;

(2) a lens;

(3) a thin opaque plate with a narrow slit which is partially blocked by a relatively wide opaque blocking patch perpendicular to the slit;

(4) a second lens similar to the first;

(5) a photocell with a .8 x 6 mm. aperture;

(6) a recorder to pick up the signal from the photocell; and

(7) a projection lens.

The focal length of the lenses, the slit length and width, and blocking patch size are in proper proportion such that the photocell signal from a straight fiber segment goes from maximum to 1/2 value when the fiber is rotated 9 ± 3° from the angle at which the maximum signal occurs.

To effect the measurement, a cross-section is placed one focal length from one of the lenses. One focal length on the other side of that lens is placed the thin plate with the slit. That location is also one focal length from the second lens which is located on the other side of the slit. On the other side of the second lens and one focal length from it is placed the (removable) photocell. The projection lens is placed behind the photocell position.

The light beam is thus directed through a cross-section, first lens, on the blocking patch over the slit (and an equal distance from the edges of the slit), through the second lens and to the photocell or projection lens.

The section image is formed on a screen by the projection lens and the section is aligned with the sample length perpendicular to the slit with a region containing no fiber segments in the .8 x 6 mm. field. The slit is rotated through 90° and the signal from the photocell is recorded when the slit makes an angle of 0° and 90° with the width of the sample. The section is then aligned with the center area of the sample in the .8 x 6 mm. field. If the sample is thicker than .8 mm. then the section is placed with one surface of the fabric just within the .8 x 6 mm. field (regions near the edge of the section are avoided). The signal is recorded with the slit length at an angle of 0° and 90° to the width of the sample. The angles are determined with an accuracy of ± 6° and a precision of ± 1°. The relative light intensity is determined with an accuracy of ± 10% and a precision of ± 2%.

The photocell signal from the sample minus the signal from the clear region is summed at 0° and at 90° for each set of ten sections cut along an axis. The total at 90° is divided by the total at 0°. The smallest value found for the two sets of sections is called the 90/0 ratio. If a sample has a low enough density, the fiber segments in the microtomed sections will be separated from each other and the 90/0 ratio is a measure of the fiber length oriented at 90° to the sample plane, to the fiber length oriented at 0°. If a sample has a high enough density, the fiber segments in the microtomed sections will be compacted and the 90/0 ratio is the ratio of the sample surface area which is oriented at 90° to the sample plane, to the surface area oriented at 0°.

EXAMPLE 1

A sheet of dry wood pulp (Buckeye Paper grade wood pulp P13) with a dry weight of 4 oz./yd.^{2} (135 g./m.^{2}) is supported on a 200 x 200 mesh per inch screen (34% open area) and passed at a speed of 3 ypm (2.7 mpm) under a row of substantially cylindrical, unbroken, vertical jet streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the paper layer. The water enters the cylindrical portion of the orifice 5.0 mils (0.127 mm.) in diameter and about 1 mil (0.025 mm.) long and exits as a stream from the frustro-conical portion which is 11 mils (0.28 mm.) long and has a diameter of about 15 mils (0.38 mm.) at the exit edge of the cone. The following sequence of treatments is used:

Passes	Pressure psi.	Pressure ($kg./cm.^2$)	Top Screen 14 x 18 mesh with about 65% open area	
2	300	(21)	yes	
2	600	(42)	yes	
2	800	(56)	yes	
2	800	(56)	no	with oscillation

This affords a total treatment of 0.8 HP-hrs./lb. of the product (1.1 Cal./g.).

Properties of the product are given in Table I.

The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

EXAMPLE 2

Kraft bleached wood pulp (Weyerhauser Pulp Co. - Kraft SG-Sulfate) is opened, beaten in water with a Waring Blendor laboratory stirrer for 15 minutes and made into a sheet. The sheet is supported on a 60 x 60 mesh per inch twill-weave wire screen (20% open area) and hydraulically entangled by passing at 8 ypm (7.3 mpm) under a row of water jets. The orifices spaced 40/inch (per 2.54 cm.) have a similar design to that of Example 1, the cylindrical portion having a diameter of 3.5 mils (0.089 mm.). The total treatment consists of 1 pass each at 500, 300 and 600 psi. (35, 18 and 42 $kg./cm.^2$, respectively) to give a total treatment of about 0.1 HP-hrs. per pound of product (0.2 Cal./g.).

Properties of the product are given in Table I.

The product has a fine pattern of very shallow grooves and furrows on one face and a replica of the screen

pattern on the other face. When viewed against a light, a regular pattern of holes is visible. The product has a soft tactile hand and because of its appearance and drape resembles a textile woven fabric.

EXAMPLE 3

A sheet of the wood pulp of Example 1 of 7.2 oz./yd.^{2} dry weight (249 g./m.^{2}) is supported on a 100 x 100 mesh per inch screen (34% open area) and passed at 3 ypm (2.7 mpm) under water jets from a row of the orifices of Example 1 spaced 20 per inch (per 2.54 cm.) for the following treatments:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
2	500	(35)	yes
2	1000	(70)	yes
2	1000	(70)	no

The sample was then flipped and the above sequence repeated to give a total treatment of 0.8 HP-hrs./lb. (1.1 Cal./g.).

The jets were oscillated for the second pass at each pressure. Properties of the product are given in Table I. The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

EXAMPLE 4

A blend of approximately 20% of rayon staple fibers, 1.25 dpf with a length of 2 inches (5.1 cm.), and 80% of opened wood pulp of Example 2, is formed into a web on a laboratory scale random web former. The resulting web is placed on a 50 x 50 mesh per inch (per 2.54 cm.) screen (20% open area) and hydraulically entangled using the apparatus and speed of Example 2 by the following sequence:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
1	300	(21)	yes
2	600	(42)	no
1	700	(49)	no

for a total treatment of about 0.2 HP-hrs./lb. (0.3 Cal./g.).

Properties of the product are given in Table I. The product has a fine pattern of very shallow grooves and furrows on one face and a slight, embossed-like replica of the screen pattern on the other face. When viewed against a light, a regular pattern of small holes is visible.

EXAMPLE 5

An aqueous dispersion containing 80% of the wood pulp of Example 1 and 20% 0.25-inch (6.3-mm.) long rayon staple of 1.5 dpf. is used to form a sheet. The sheet is supported on an 80 x 80 mesh per inch (per 2.54 cm.) screen (19% open area) and passed at 3 ypm (2.7 mpm) under a row of water streams from a row of funnel-shaped orifices having a 3.0 mil (0.076 mm.) diameter cylindrical section and spaced 40 per inch (per 2.54 cm.) by the following sequence:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
2	400	(28)	yes
2	600	(42)	yes
2	800	(56)	yes

The sample was then flipped and the above sequence repeated for a total treatment of about 0.4 HP-hrs./lb. (0.6 Cal./g.).

Properties of the product are given in Table I. The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

EXAMPLE 6

An aqueous dispersion containing 80% of a kraft wood pulp and 20% of 0.375-inch (9.5-mm.) long, 1.5 dpf rayon staple is used to form a sheet. The sheet is supported on a 180 x 180 mesh per inch (per 2.54 cm.) screen (37% open area) and passed at 10 ypm (9.2 mpm) under water streams of the apparatus of Example II by the following procedure:

Passes	Pressure psi.	Pressure ($kg./cm.^2$)	Top Screen	Jets Oscillated
1	500	(35)	yes	yes
1	1000	(70)	yes	yes
1	1000	(70)	no	no

The sample was then flipped and further treated as follows:

1	1000	(70)	no	yes

for a total treatment of about 0.2 HP-hrs./lb. (0.3 Cal./g.) to make product A.

The above procedure is repeated substituting 0.75-inch (1.9-cm.) long rayon staple for the shorter rayon above to make product B. A sample of B is then placed on a 20 x 20 mesh per inch (per 2.54 cm.) screen (19% open area) and hydraulically treated following the same general procedure for an additional 0.06 HP-hrs./lb. (0.085 Cal./g.) to yield product C.

Products A and B have the appearance of a felt material. Product C more nearly resembles a woven fabric with a pattern of apertures of about 5 - 7 mm. in diameter.

TABLE I

Example	Fabric Weight oz/yd2 (g./m2)	Strip Tensile MD x CD lb/in//oz/yd2 (g/cm//g/m2)	Elongation MD x CD %	Modulus MD x CD lb/in//oz/yd2 (g/cm//g/m2)	90/0 Ratio	Density g/cm3	Drape Flex cm MD x CD	Opacity %	Abrasion Resistance minutes
1	2.7 (92)	0.8 (4.2)	37		0.83	0.14			8
2	2.6 (88)	1.0 x 1.2 (5.3 x 6.3)	24 x 23	12 x 11 (64 x 58)	0.42	0.11	3.4	80	2.9
3	5.9 (196)	1.6 (8.5)	52	7 (37)	1.1	0.15	3.6	88	> 110
4	2.6 (88)	2.3 x 1.8 (12 x 9.5)	43 x 55	4 x 4 (21 x 21)	0.38	0.12	3.6 x 3.5	67	5.4
5	5.3 (180)	1.8 (9.5)	43	9 (48)	0.78	0.18	3.6	89	>35
6A	1.8 (61)	0.9 x 0.9 (4.8 x 4.8)	40 x 30	3 x 7 (16 x 37)	0.48	0.14	2.2 x 2.9	69	4
6B	1.7 (58)	1.2 x 1.2 (6.3 x 6.3)	31 x 36	8 x 7 (42 x 37)	0.45	0.14	2.1 x 1.7	73	1
6C	2.0 (68)	1.1 x 0.9 (5.8 x 4.8)	32 x 32	7 x 5 (37 x 26)	0.63	0.13	1.7 x 1.9	66	-

EXAMPLE 7

Rayon fibers of 1.56-inch (3.94-cm.) length and 1.5 dpf are made into a web having a weight of 0.7 oz./yd.^{2} (24 g./m.^{2}) of randomly oriented fibers by an air deposition process using a Rando-Webber machine (made by Curlator Corporation of East Rochester, N.Y.).

The above web is placed on a 60 x 60 mesh screen, covered with a sheet of a commercial saturation paper made of soft wood pulp having a dry weight of 1.9 oz./yd.^{2} (64 g./m.^{2}) and passed at a speed of 8 ypm (7.3 mpm) under a row of substantially cylindrical, unbroken vertical jet streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the paper layer. The water enters the cylindrical portion of the orifice 3.5 mils (0.089 mm.) in diameter and about 2 mils (0.051 mm.) long and exits as a stream from the frustro-conical portion which is 10 mils (0.25 mm.) long and has a diameter of about 11 mils (0.28 mm.) at the exit edge of the cone. The following sequence of treatments is used:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
1	200	(14)	yes
1	600	(42)	yes
1	600	(42)	no
1	800	(56)	no

This affords a total treatment of about 0.1 HP-hrs./lb. of the product (0.2 Cal./g.).

Properties of the product are given in Table II.

EXAMPLE 8

The procedure of Example 7 is repeated with the exception that the rayon staple web is hydraulically entangled for a total energy of 0.3 HP-hr./lb. at pressures not exceeding 800 psi. (56 kg./cm.^{2}) before it is assembled as the bottom side of a composite web. The composite web is hydraulically entangled using the equipment and procedure of Example 7, using 1 pass at 300 psi. (21 kg./cm.^{2}) with the top screen and a second pass at 800 psi. (56 kg./cm.^{2}) without a top screen for a total treatment of 0.06 HP-hrs./lb. of product (0.085 Cal./g.).

Properties of the product are given in Table II.

EXAMPLE 9

Woven cotton tobacco cloth weighing 0.45 oz./yd.^{2} (15 g./m.^{2}) is covered with a sheet of a paper (density 0.39 g./cm.^{3}) made from a soft wood pulp (Buckeye P13) weighing 1.8 oz./yd.^{2} (61 g./m.^{2}) and the composite web hydraulically entangled using the equipment and speeds of Example 7 for 1 pass at 500 psi. (35 kg./cm.^{2}) with a top screen and 2 passes at 800 psi. (56 kg./cm.^{2}) without a top screen for a total treatment of about 0.2 HP-hrs./lb. of product (0.3 Cal./g.).

Properties of the product are given in Table II.

EXAMPLE 10

A urethane foam sheet 0.25-inch (6.3-mm.) thick with a weight of 2.2 oz./yd.^{2} (75 g./m.^{2}) is covered with 2 sheets of a commercial paper hand towel having a dry weight of 1.45 oz./yd.^{2} (49 g./m.^{2}) per sheet. The composite web is placed on a 20 x 20 mesh screen and passed

at 2 ypm (1.8 mpm) under streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the web. The water enters the cylindrical portion of the orifice 5 mils (0.13 mm.) in diameter and about 1 mil (0.025 mm.) long and exits as a stream from the frustro-conical portion which is 11 mils (0.28 mm.) long and has a diameter of about 15 mils (0.38 mm.) at the exit edge of the cone. The sequence of treatment follows:

Passes	Pressure psi.	Pressure (kg./cm.^{2})	Top Screen
1	500	(35)	yes
1	1000	(70)	no
1	800	(56)	no
1	1000	(70)	no

This gives a total treatment of 1.4 HP-hrs./lb. of product, (2 Cal./g.). Properties of the product are given in Table II. The product has a very abrasion resistant surface with fabric-like tactile aesthetics.

EXAMPLE 11

The starting layer of textile fibers is a 1.8 oz./yd.^{2} (61 g./m.^{2}) weight web containing 88% of poly-(ethylene terephthalate) continuous filament of 3 dpf with a potential self-elongation of 8 - 10% and 12% of poly-(ethylene isophthalate/terephthalate) copolymer continuous filaments of 2.3 dpf. The web is prepared by the process of British Patent No. 932,482 and has been compressed at about 100°C. to consolidate the web without fusing the copolymer binder filaments. The web is hydraulically entangled to a strong nonwoven by treatment on a 40 mesh

(21% open area) screen with streams from the 5 mil diameter orifices of Example 10 for a total of 2.2 HP-hrs./lb. (3.1 Cal./g.).

A sheet of kraft paper with a dry weight of 2.7 oz./yd.^{2} (92 g./m.^{2}) is placed on top of the above entangled web and screen and passed under the above water streams at 2 ypm (1.8 mpm) as follows:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
2	300	(21)	yes
2	600	(42)	yes
2	1000	(70)	yes
2	1000	(70)	no

This affords a total energy of 1.4 HP-hrs./lb. for the composite structure. The nonwoven fabric is dried and then ironed with a hand iron using "Linen" setting to melt the binding fibers.

The product has a remarkable abrasion resistance of over 270 minutes. For comparison, the initial (unentangled) polyester fiber web after bonding by ironing has an abrasion resistance of only 7 minutes.

Properties of the product are given in Table II.

EXAMPLE 12

High wet modulus rayon (dry tenacity 4.9 gpd, wet tenacity 3.4 gpd) staple of 1.25 dpf and 2-inch (5.1-cm.) length is made into a randomly oriented web of 0.3 oz./yd.^{2} (10 g./m.^{2}) weight.

The above textile fiber web is placed on a 150 x 150 mesh screen, covered with a layer of kraft paper with a dry weight of 1.0 oz./yd.^{2} (34 g./m.^{2}) and passed at 2 ypm

(1.8 mpm) under the water streams of the orifices of Example 7 according to the following schedule:

Passes	Pressure psi.	(kg./cm.^{2})	Top Screen
1	400	(28)	yes
1	500	(35)	no
web flipped			
1	500	(35)	no

for a total energy of 0.4 HP-hrs./lb. (0.56 Cal./g.).

The above non-foraminous web is then placed on a 20 x 20 mesh screen (19% open area) with the paper face up and passed twice under the streams at 500 psi. (35 kg./cm.^{2}) with the orifices oscillating for a treatment energy of 0.25 HP-hrs./lb. (0.35 Cal./g.). The product is a foraminous nonwoven having a square pattern of apertures about 5-7 mm. in diameter. Properties are given in Table II.

If one attempts to make the above product directly by doing all of the hydraulic treatment on the coarse screen with the same total energy input, it is found that the product is significantly weaker than above and that a significant amount of paper fibers are washed away.

EXAMPLE 13

A randomly oriented web of 0.5 oz./yd.^{2} (17 g./m.^{2}) weight containing polyester staple of 1.5-inch (3.8-cm.) length and 1.5 dpf is placed on a 60 x 60 mesh screen. It is covered with a sheet of soft wood pulp paper having a dry weight of 1.6 oz./yd.^{2} (54 g./m.^{2}) and hydraulically entangled using the water streams and

sheet velocity of Example 7, by the following sequence:

Passes	Pressure psi.	($kg./cm.^2$)	Top screen
1	500	(35)	yes
1	600	(42)	no
1	300	(21)	yes
1	600	(42)	no

The total treatment energy is 0.14 HP-hrs./lb. (0.2 Cal./g.). Properties of the product are given in Table II.

EXAMPLE 14

(a) A random web of the rayon fibers of Example 12, with a weight of 0.5 $oz./yd.^2$ (17 $g./m.^2$), is placed on a 150 x 150 mesh screen (37% open area) and covered with a sheet of kraft paper /tensile strength of 4.2 lb./in. per $oz./yd.^2$ (22 g./cm. per $g./m.^2$) and 3% elongation/ with a dry weight of 2.0 $oz./yd.^2$ (68 $g./m.^2$) and passed at 10 ypm (9.1 mpm) under water streams from the orifices of Example 7 as follows:

Passes	Pressure psi.	($kg./cm.^2$)	Top Screen
1	1200	(84)	yes
2	1500	(105)	no
web flipped			
1	1500	(105)	no

for a total energy of about 0.3 HP-hrs./lb. (0.5 Cal./g.). The properties of the product are reported in Table II and include an excellent value for abrasion resistance of 30 minutes. The product is laundered and tumble-dried in a conventional household combination machine, using a cotton

setting, without noticeable effect on its appearance or utility as a fabric.

(b) The above procedure is repeated with the substitution of a sheet of kraft paper with a dry weight of 1 oz./yd.^{2} (34 g./m.^{2}) for the heavier paper in (a) and the addition of a layer of the 1 oz./yd.^{2} paper beneath the rayon web. Properties of the product are given in Table II. It should be noted that this particular technique gives a 12% loss of the starting fibers. The product has an abrasion resistance of 20 minutes.

EXAMPLE 15

A randomly oriented web of the rayon staple of Example 7 is hydraulically entangled at up to 700 psi. on a 20 x 20 mesh screen (19% open area) to give a nonwoven fabric of 1 oz./yd.^{2} (34 g./m.^{2}) weight.

(a) A sheet of soft wood pulp paper of Example 9 with a dry weight of 3 oz./yd.^{2} (102 g./m.^{2}) is placed on top of the above rayon nonwoven fabric and the composite passed at 3 ypm (2.7 mpm) under water streams from the orifices of Example 10 while resting on an 80 x 80 mesh screen (13% open area) as follows:

Passes	Pressure psi.	Pressure (kg./cm.^{2})	Top Screen
2	300	(21)	yes
2	600	(42)	yes
2	800	(56)	yes
2	800	(56)	no

for a treatment of about 0.8 HP-hrs./lb. (1.1 Cal./g.) to give item (a).

(b) The procedure is repeated to make item (b) with the substitution of a web containing 20% of 0.25-inch (6.3-mm.) rayon fibers and 80% wood pulp for the 100% wood pulp layer used for item (a).

Properties of the products are given in Table II.

(c) In a similar way, a product is prepared in which the paper layer is sandwiched between two outer layers of textile fibers. The product has high absorbency and a soft textile hand. It is suitable for use as a towel, or for absorbent pads.

TABLE II

Example	Fabric Weight oz/yd2 (g./m²)	Strip Tensile MD x CD lb/in//oz/yd2 (g/cm//g/m²)	Elongation MD x CD %	Modulus MD x CD lb/in//oz/yd2 (g/cm//g/m²)	90/0 Ratio	Density g/cm³	Drape Flex cm	Opacity %	Abrasion Resistance minutes
7	2.4 (81)	2.3 x 2.9 (12 x 15)	44 x 53	12 x 7 (63 x 37)		0.14	3.7 x 3.0	69	0.5
8	2.3 (78)	3.2 x 2.3 (17 x 12)	37 x 62	13 x 4 (69 x 21)	0.52	0.13	3.5 x 3.0	67	1.5
9	3.6 (122)	4.2 x 3.1 (22 x 16)	45 x 48	5 x 4 (26 x 21)	0.62	0.14	3.0 x 2.6	71	3.0
10	2.8 (95)	1.0 (5)	67	2 (10)	0.71	0.09	3.7	96	7.8
11	3.7 (126)	5.2 x 5.2 (27 x 27)	128 x 142	12 x 11 (63 x 58)	0.44	0.13	3.8	77	270
12	1.4 (47)	2.6 x 2.0 (14 x 11)	37 x 47	10 x 7 (53 x 37)	0.70	0.08	2.6 x 2.7	44	
13	2.1 (71)	2.3 x 2.2 (12 x 12)	41 x 37	8 x 8 (42 x 42)	0.58	0.13	2.1 x 1.8	69	4.8
14a	2.5 (85)	3.4 x 2.9 (18 x 15)	45 x 53	8 x 4 (42 x 21)		0.17	2.5 x 2.5	79	30
14b	2.2 (75)	2.8 x 2.9 (15 x 15)	33 x 45	10 x 8 (53 x 42)					20
15a	3.8 (129)	1.4 x 1.7 (7.4 x 9)	39 x 54	2 x 3 (11 x 16)	0.72	0.15	2.1	81	10
15b	4.3 (146)	2.5 x 1.8 (13 x 10)	47 x 42	6 x 4 (31 x 21)	0.83	0.19	2.5	84	60

EXAMPLE 16

The starting layer of textile fibers is a 1.6 oz/yd^2 (54 g/m^2) weight web containing 88% of poly(ethylene terephthalate) continuous filaments of 3 dpf (with a potential spontaneous elongation of 12% upon heating at 200°C. or higher) and 12% of the copolymer poly(ethylene isophthalate/terephthalate) (80/20%) continuous filaments of 3 dpf. The random web is prepared by the process of British Patent No. 932,482 and the homopolymer fibers are processed according to U. S. Patent No. 2,952,879 to provide the potential elongation.

The above random web is placed on a 60 x 60 mesh screen (16% open area), covered with a sheet of kraft wood pulp weighing 1.5 oz/yd^2 (51 g/m^2) and a 14 x 18 mesh (65% open area) screen placed on top. The entire assembly is passed under the water streams of Example 10. The top screen is removed and the treatment continued at 1000 and 1500 psi (70 and 105 kg/cm^2) until a total energy of 1.0 HP-hrs/lb is applied to the sample. The fabric is a well entangled product of this invention.

The dry fabric is passed between moving screens through which air at 230°C. is passed to melt the copolymer fiber and further bond the structure. The surface of the fabric that faced the water streams is composed largely ($\geq$75%) of paper fibers, the ends of which are bent down and embedded in the structure. The other side of the fabric has paper fiber ends protruding from the polyester web, which is somewhat rearranged and interpenetrated and entangled by the paper fibers.

The bonded product has the following properties:

Fabric weight	3.1 oz/yd^2	($105\ g/m^2$)
Density	0.14 g/cm^3	
Strip tensile M.D.	5.7 $lb/in//oz/yd^2$	($30\ g/cm//g/m^2$)
C.D.	6.0 "	(32 ")
Modulus, 5% M.D.	20 "	(105 ")
C.D.	13 "	(68 ")
Drape flex M.D. x C.D.	5.8 x 4.8 cm	
Opacity	83%	
Abrasion resistance	56 minutes	
90/0 ratio	0.46	

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The improvement in the conventional paper-making process of preparing a stock suspension of fibers in water, continuously screening fibers from the stock to form a wet mat, mechanically removing water from the mat to form a sheet, wherein the improvement comprises thereafter supporting the sheet on an apertured backing member at a distance from orifices in a manifold which provides water, and jetting water on said sheet, said water supplied to said manifold at pressures of 200 to 2000 pounds per square inch to said orifices to form streams having an energy flux of at least 23,000 foot-poundals/in.^{2} second and a diameter of 2 to 10 mils at the treatment distance from said orifices, traversing the supported sheet with the streams until a stream energy of 0.05 to 2.0 horsepower-hours per pound of product has been applied, and drying the product.

2. The process defined in Claim 1 wherein the sheet is traversed with the streams while supported on a fine mesh screen to produce a felt-like product.

3. The process defined in Claim 1 wherein the sheet is traversed with a stream energy of 0.05 to 2.0 horsepower-hours per pound of product while supported on a fine mesh screen and is then treated with a stream energy of 0.05 to 1.0 horsepower-hour per pound while supported on a coarse apertured patterning memeber to form a patterned product.

4. The process defined in Claim 3 wherein the coarse apertured patterning member is a woven wire screen of about 10 to 30 mesh per inch and the appearance of the product resembles that of a woven textile fabric.

5. The process defined in Claim 1 wherein said fibers consist essentially of 75% to 100% paper fibers and 0% to 25% textile staple fibers by weight.

6. The process defined in Claim 1 wherein said sheet is assembled on top of a layer of textile staple fibers, the assembly is supported on the apertured backing member and the supported assembly is traversed with the streams to form a laminated product.

7. The process of Claim 5 or Claim 6 characterized in that the sheet is dried before being traversed with the water streams.

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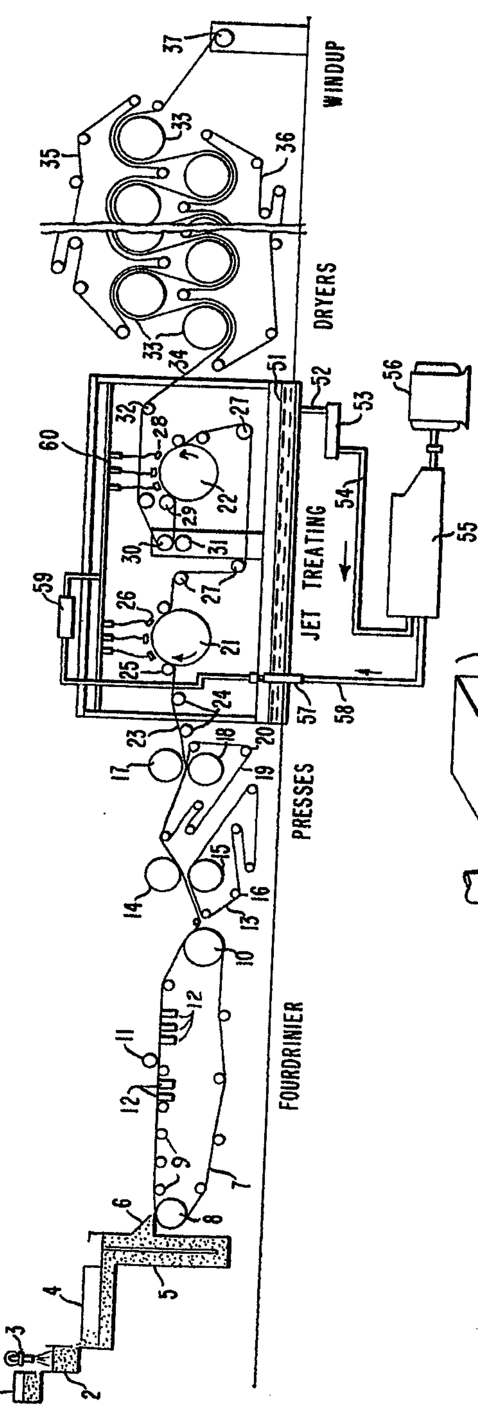
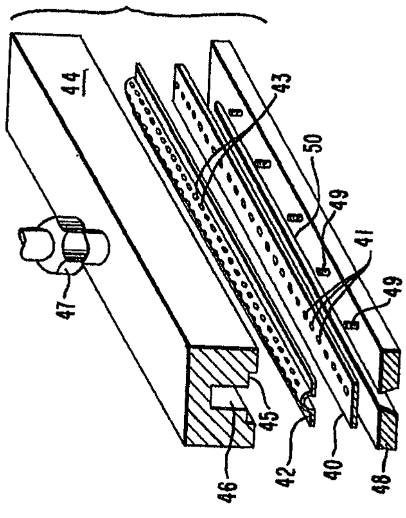
CANADA



F I G. 1



F I G. 2

INVENTOR

CHARLES SHAMBELAN

PATENT AGENT

United States Patent [19]

Sternlieb et al.

[11] Patent Number: 4,967,456

[45] Date of Patent: Nov. 6, 1990

[54] APPARATUS AND METHOD FOR HYDROENHANCING FABRIC

[75] Inventors: Herschel Sternlieb, Brunswick, Me.; Jodie M. Siegel, Watertown; John M. Greenway, Westwood, both of Mass.

[73] Assignee: International Paper Company, Purchase, N.Y.

[21] Appl. No.: 382,160

[22] PCT Filed: Apr. 14, 1989

[86] PCT. No.: US85/01593

§ 371 Date: May 18, 1989

§ 102(e) Date: May 18, 1989

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned, which is a continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned.

[51] Int. Cl.[5] D04H 1/46

[52] U.S. Cl. .... 28/104; 8/151.2; 28/167; 68/205 R; 428/225

[58] Field of Search .... 28/104, 167; 8/151.2; 68/205 R; 428/225

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,241,222	5/1941	Sonnino	26/2
3,485,706	12/1969	Evans	161/72
3,498,874	3/1970	Evans et al.	161/109
3,542,632	2/1969	Eickhoff	161/65
3,873,255	3/1975	Kalwaites	425/83
3,917,785	11/1975	Kalwaites	264/108
4,144,370	3/1979	Boulton	428/233
4,145,468	3/1979	Mizoguchi et al.	428/239
4,146,663	3/1979	Ikeda et al.	428/96
4,156,957	6/1979	McKay	28/159
4,190,695	2/1980	Niederhauser	428/234
4,233,349	11/1980	Niederhauser	428/92
4,497,095	2/1985	Minemura et al.	26/2 R
4,499,637	2/1985	Greenway	26/2 R
4,695,500	9/1987	Dyer et al.	428/134

FOREIGN PATENT DOCUMENTS

287821	9/1964	Australia .	
739652	8/1966	Canada	28/76
0177277	9/1985	European Pat. Off. .	
7410272	3/1974	France	26/352
61-55253	3/1986	Japan .	

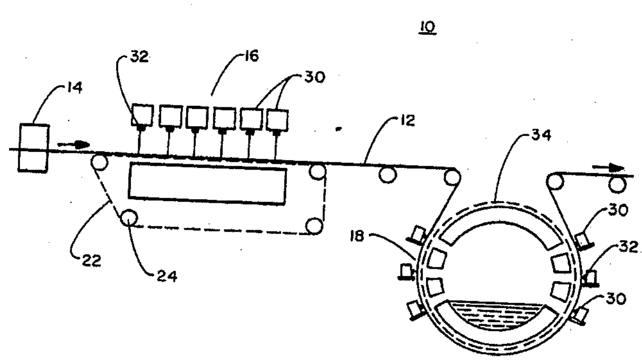
Primary Examiner—Philip R. Coe

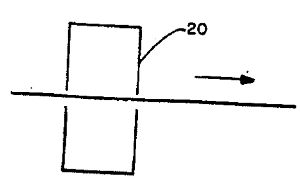
Attorney, Agent, or Firm—Francis J. Clark

[57] **ABSTRACT**

An apparatus 10 and related process for enhancement of woven and knit fabrics through use of dynamic fluids which entangle and bloom fabric yarns. A two stage enhancement process is employed in which top and bottom sides of the fabric are respectively supported on members 22, 34 and impacted with a fluid curtain including high pressure jet streams. Controlled process energies and use of support members 22, 34 having open areas 26, 36 which are aligned in offset relation to the process line produces fabrics having a uniform finish and improved characteristics including, edge fray, drape, stability, abrasion resistance, fabric weight and thickness.

41 Claims, 17 Drawing Sheets





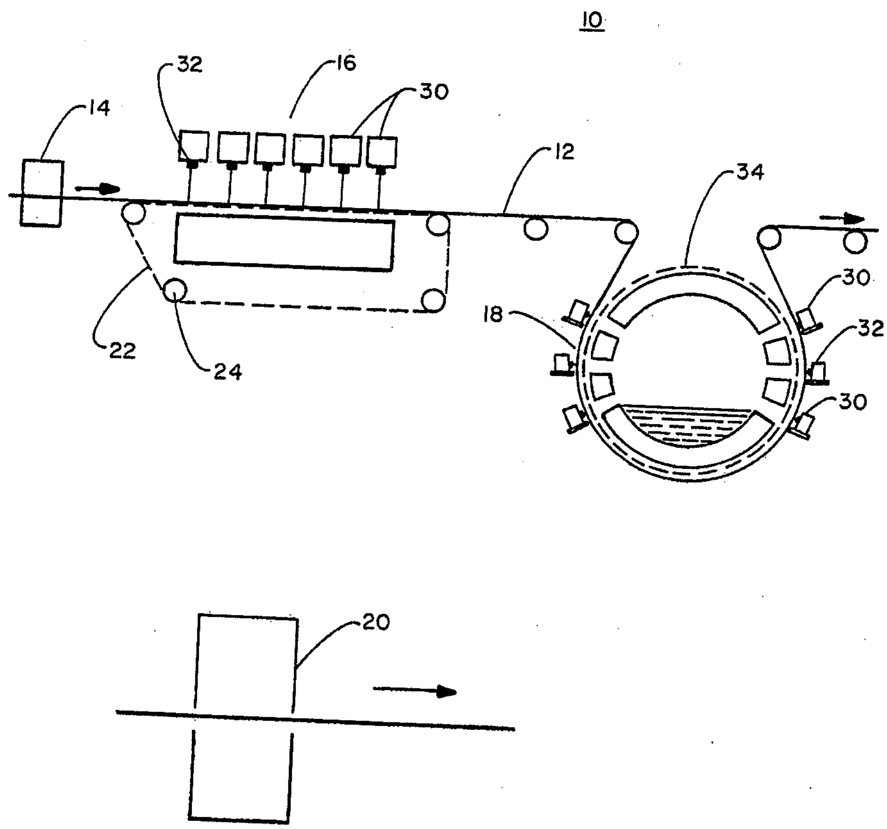


FIG. 1

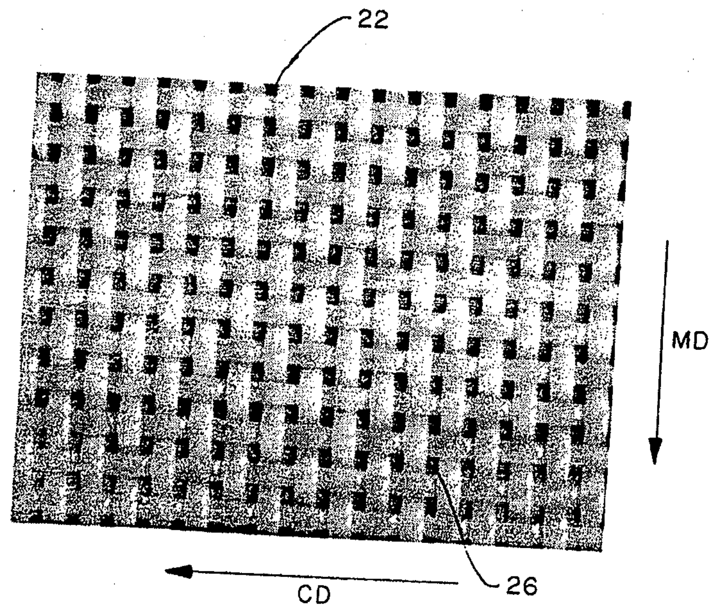


FIG. 2A

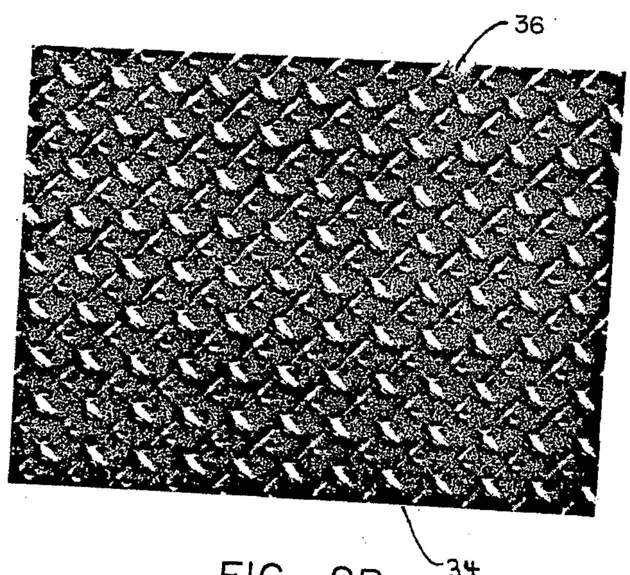


FIG. 2B

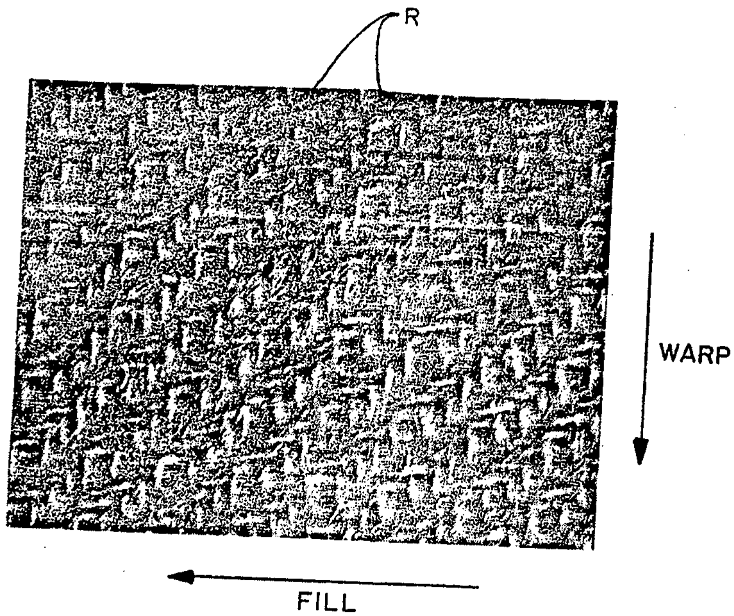


FIG. 3A

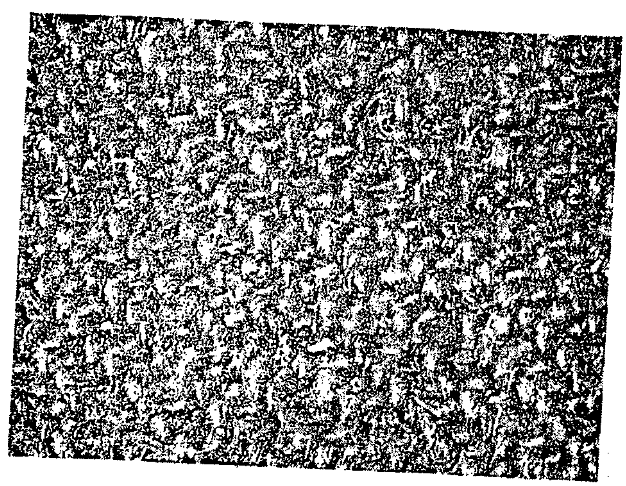


FIG. 3B

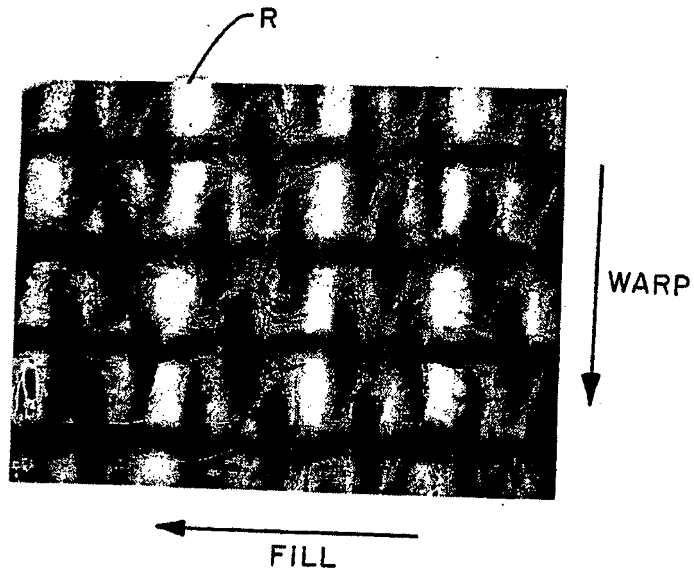


FIG. 4A

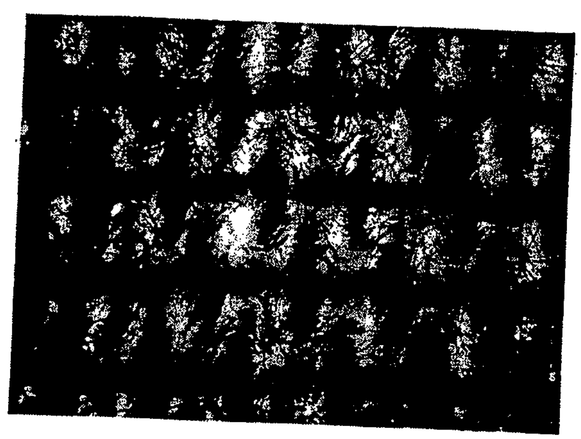


FIG. 4B

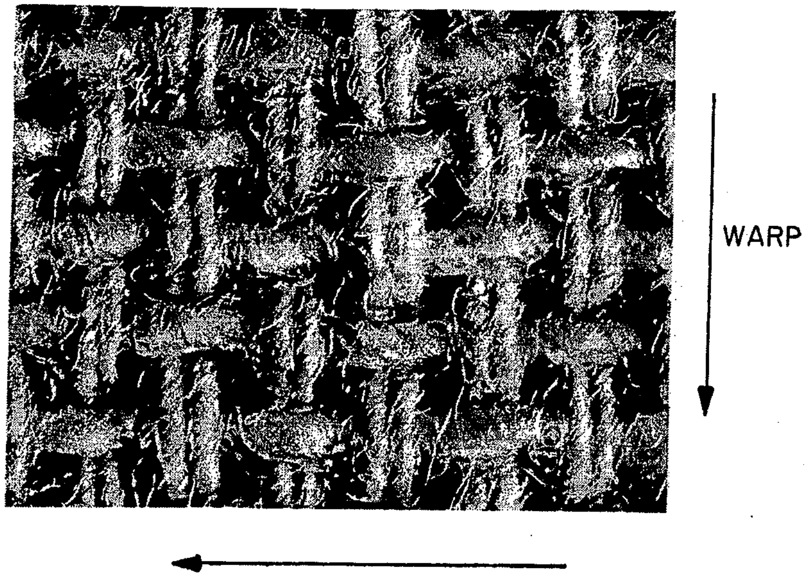


FIG. 5A

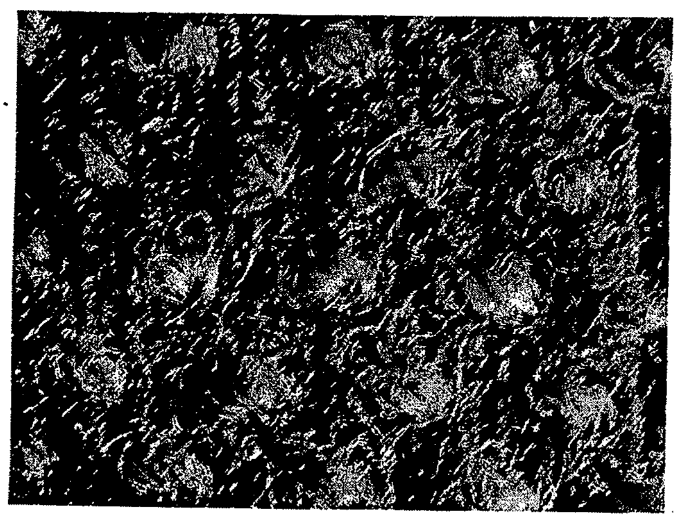


FIG. 5B

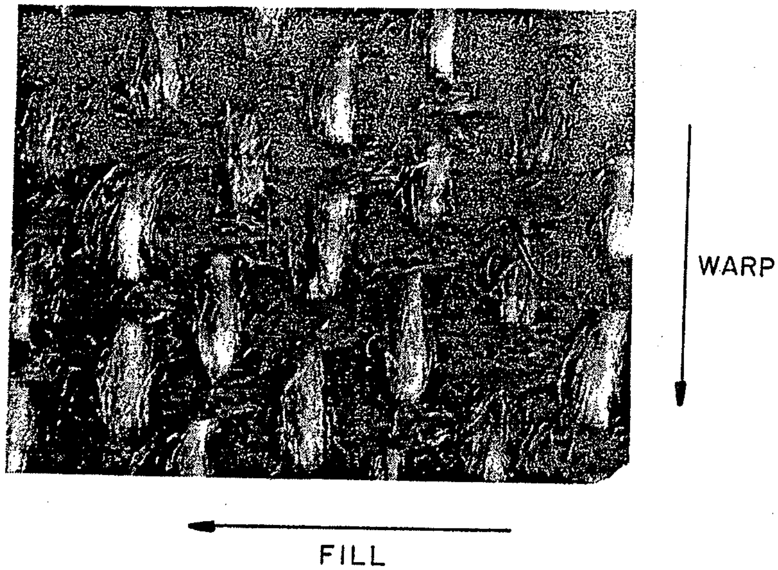


FIG. 6A

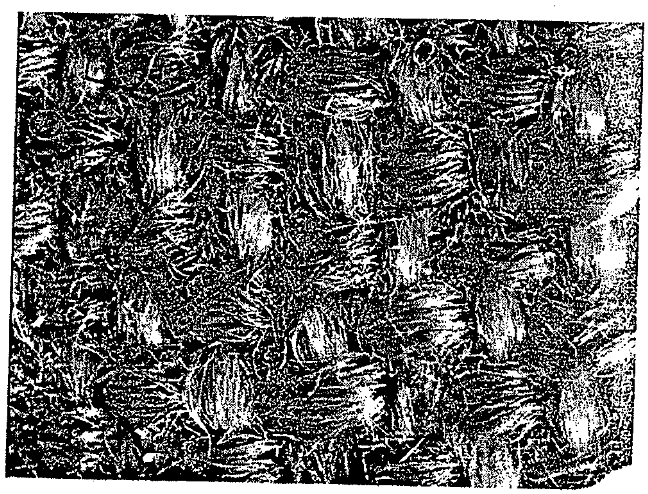


FIG. 6B

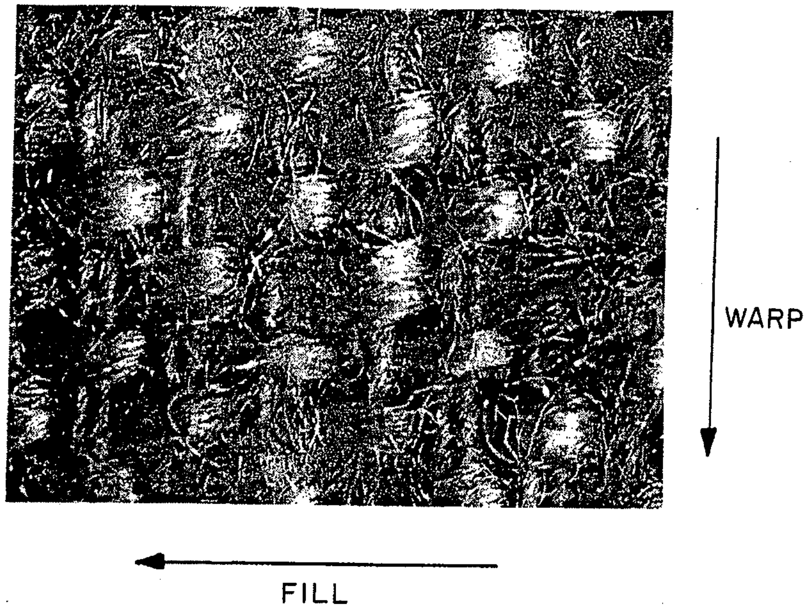


FIG. 7A

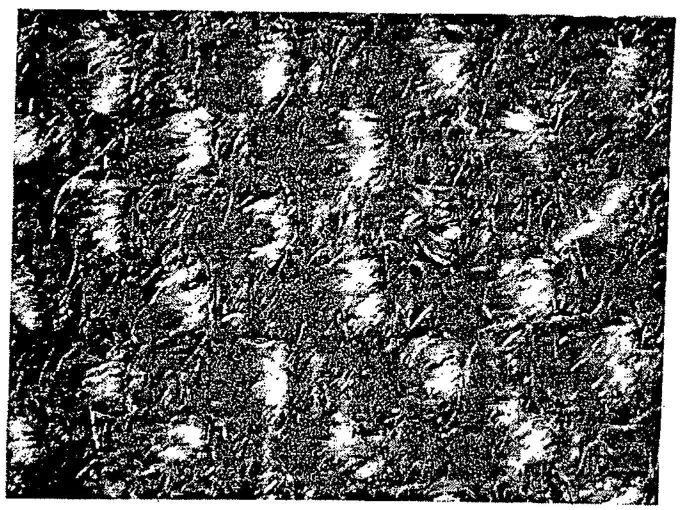


FIG. 7B

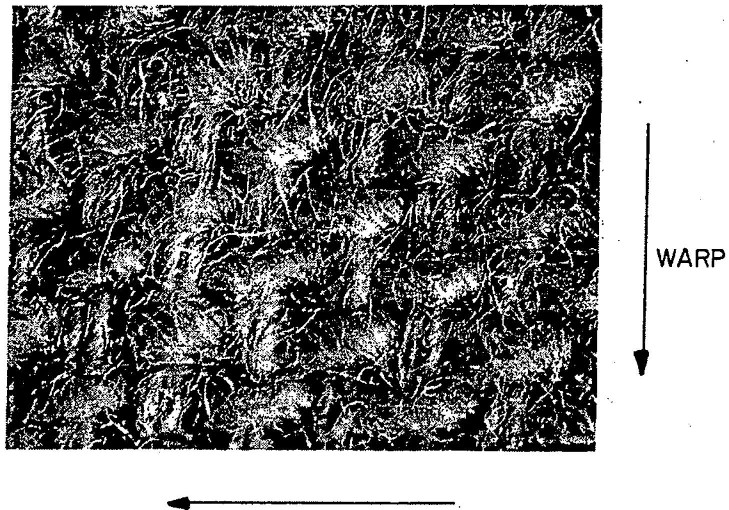


FIG. 8A

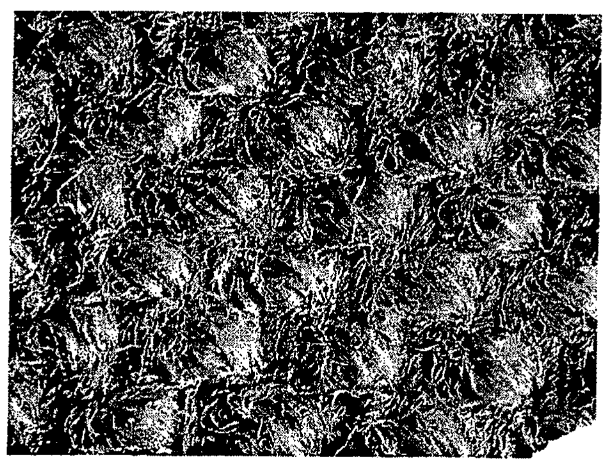


FIG. 8B

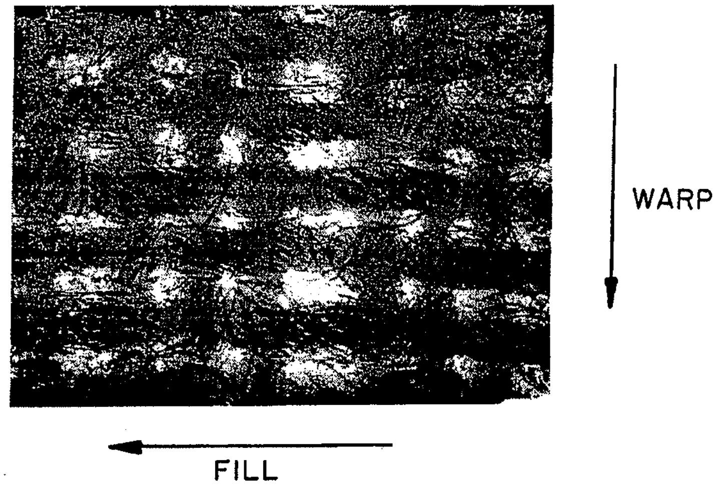


FIG. 9A

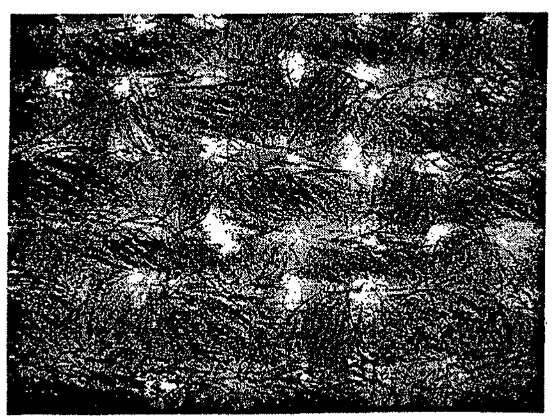


FIG. 9B

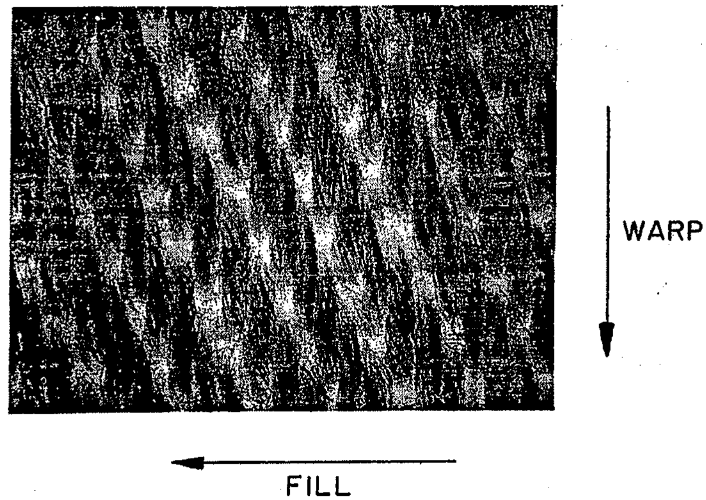


FIG. 10A

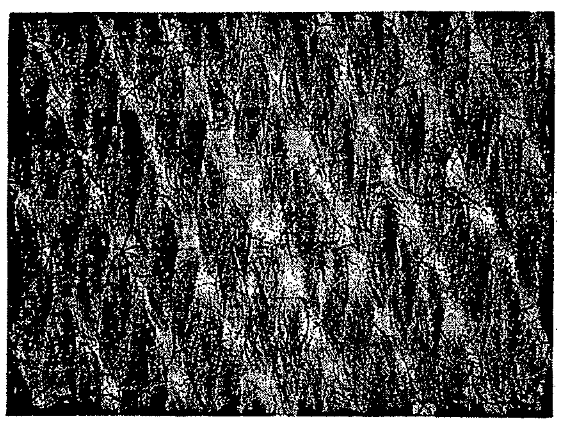


FIG. 10B

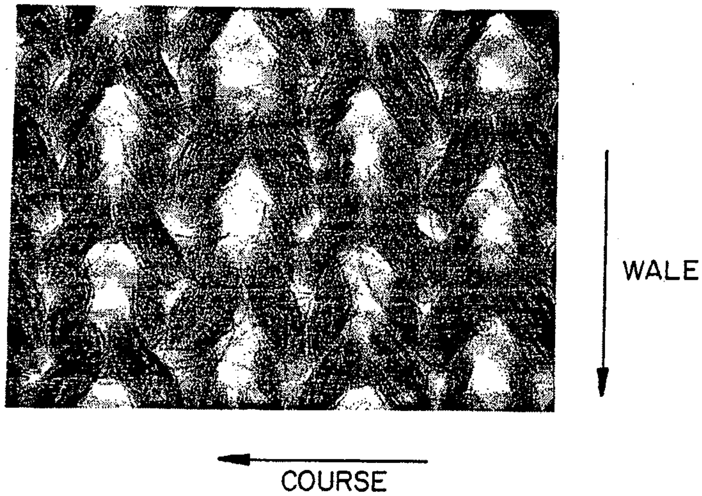


FIG. 11A

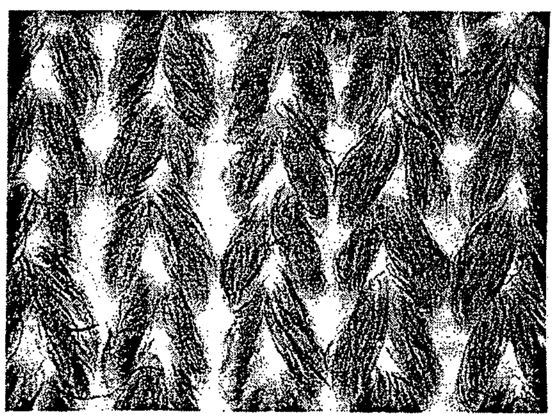


FIG. 11B

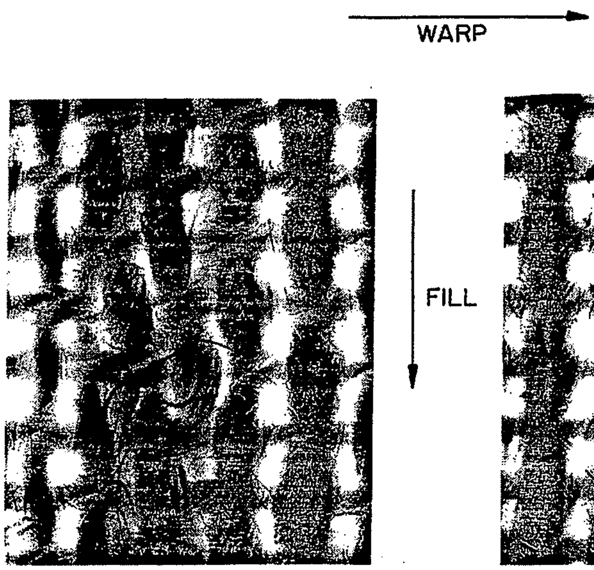


FIG. 12A

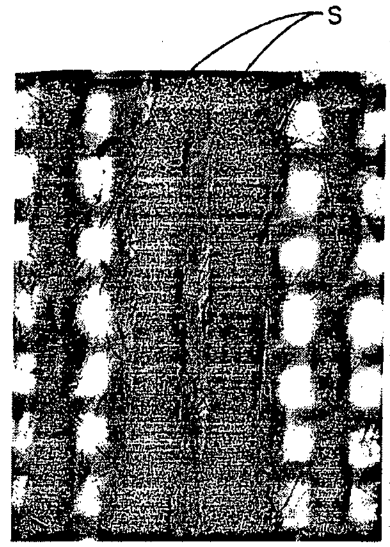


FIG. 12B

FIG. 13A

FIG. 13B

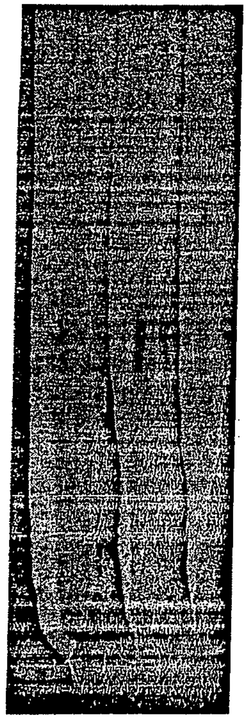


FIG. 14A

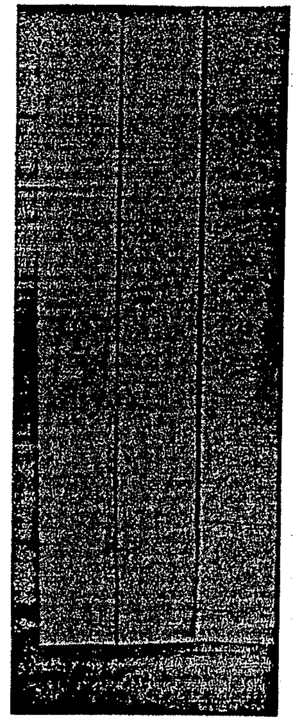


FIG. 14B

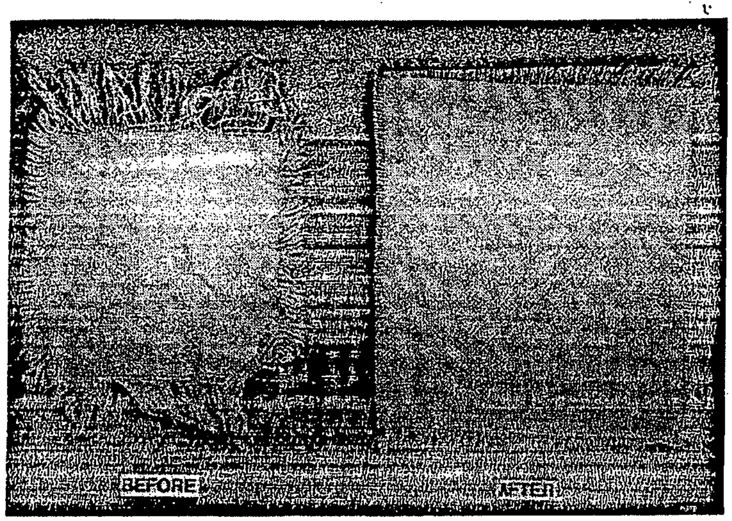


FIG. 15A

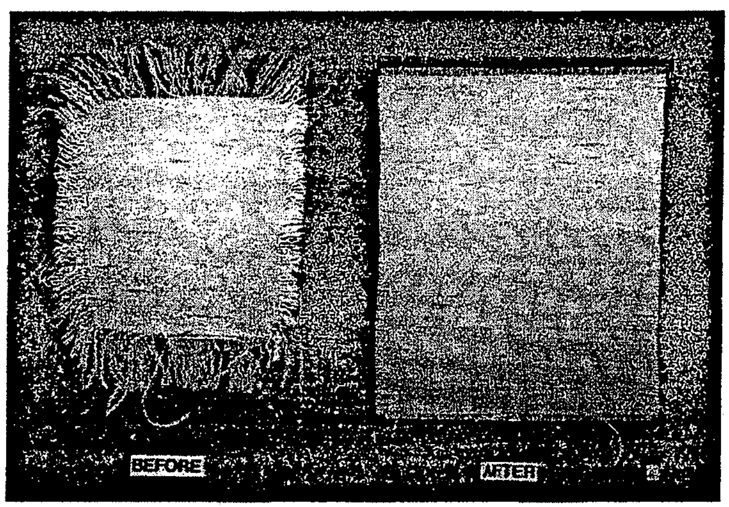


FIG. 15B

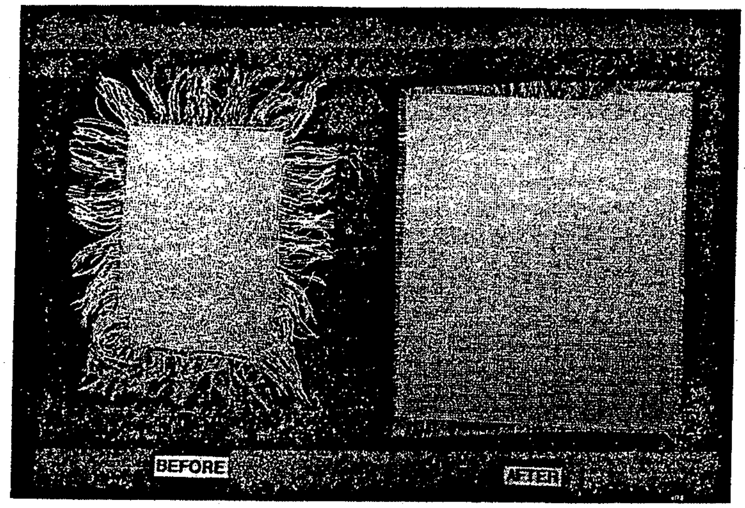


FIG. 15C

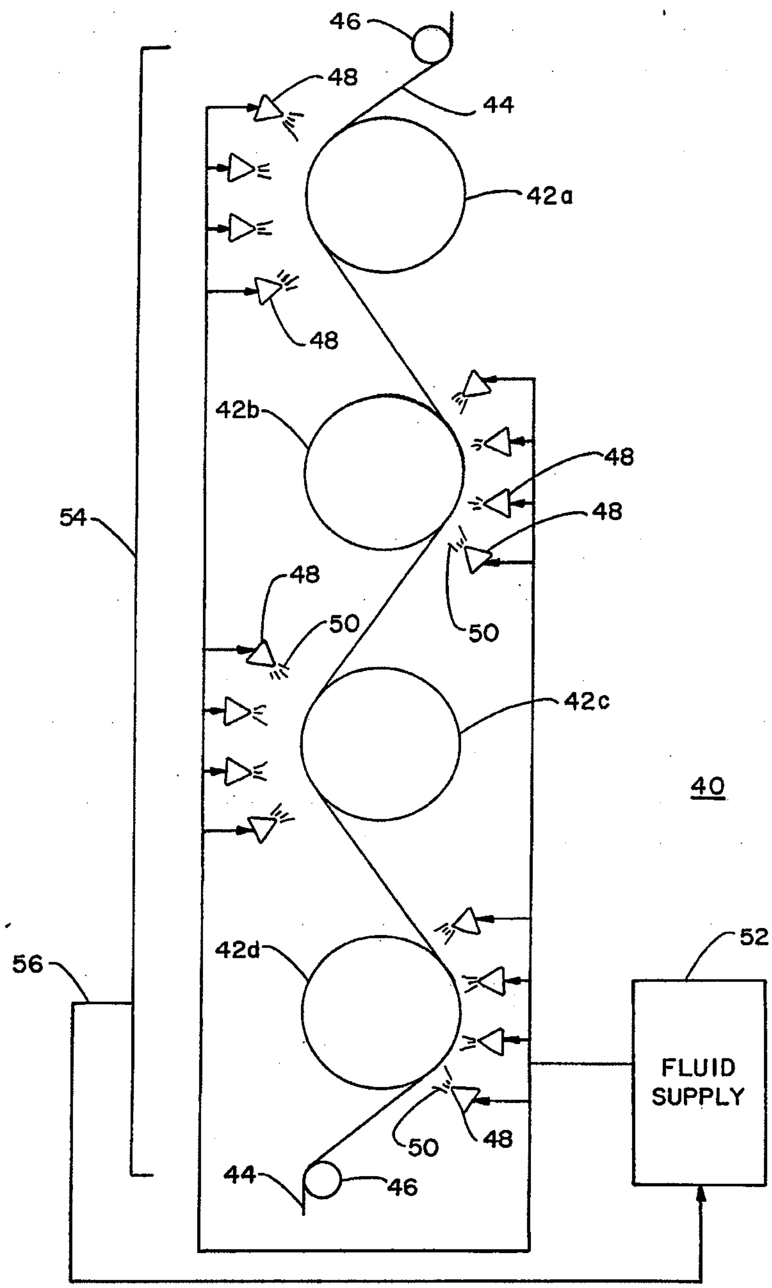

46
48
44
42a
48
42b
48
48
54
48
50
50
42c
40
52
56
42d
FLUID SUPPLY
50
48
44
46

FIG. 16

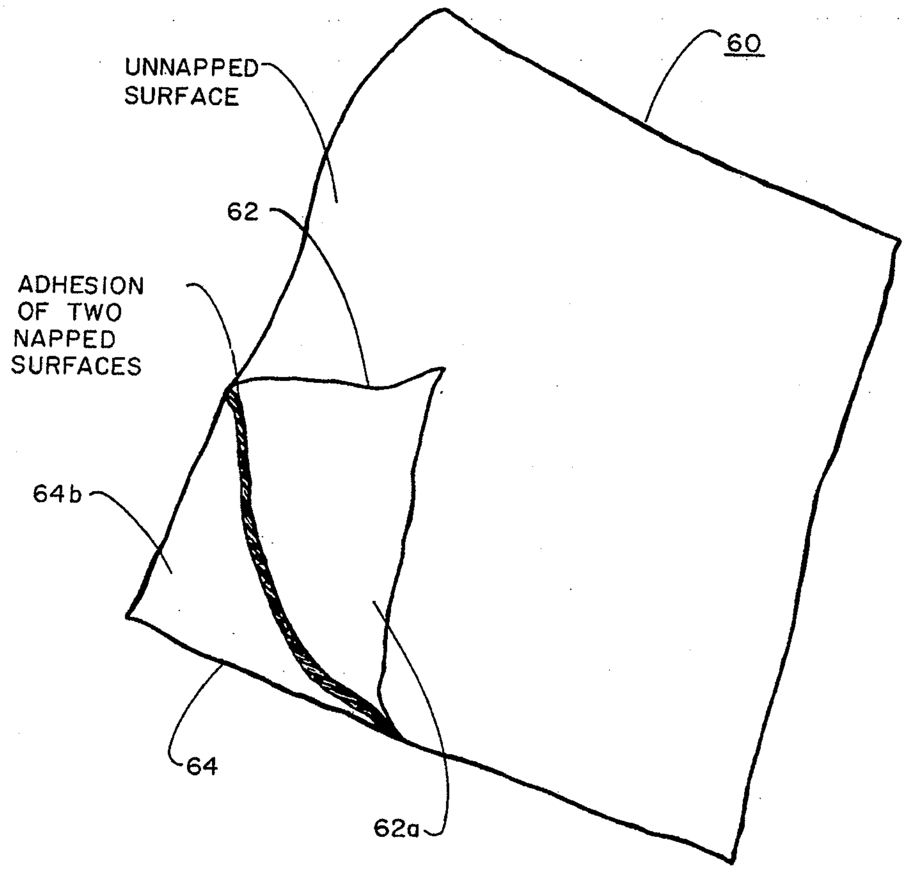

60
UNNAPPED SURFACE
62
ADHESION OF TWO NAPPED SURFACES
64b
64
62a

FIG. 17

APPARATUS AND METHOD FOR HYDROENHANCING FABRIC

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. Nos. 07/041,542 and 07/184,350, respectively filed Apr. 23, 1987; and Apr. 21, 1988, and now both abandoned.

FIELD OF INVENTION

This invention generally relates to a textile finishing process for upgrading the quality of woven and knit fabrics. More particularly, it is concerned with a hydroentangling process which enhances woven and knit fabrics through use of dynamic fluid jets to entangle and cause fabric yarns to bloom. Fabrics produced by the method of the invention have enhanced surface finish and improved characteristics such as cover, abrasion resistance, drape, stability as well as reduced air permeability, wrinkle recovery, seam slippage, and edge fray.

BACKGROUND ART

The quality of a woven or knit fabric can be measured by various properties, such as, the yarn count, thread count, abrasion resistance, cover, weight, yarn bulk, yarn bloom, torque resistance, wrinkle recovery, drape and hand.

Yarn count is the numerical designation given to indicate yarn size and is the relationship of length to weight.

Thread count in woven or knit fabrics, respectively, defines the number ends and picks, and wales and courses per inch of fabric. For example, the count of cloth is indicated by enumerating first the number of warp ends per inch, then the number of filling picks per inch. Thus, 68×72 defines a fabric having 68 warp ends and 72 filling picks per inch.

Abrasion resistance is the ability of a fabric to withstand loss of appearance, utility, pile or surface through destructive action of surface wear and rubbing.

Cover is the degree to which underlying structure in a fabric is concealed by surface material. A measure of cover is provided by fabric air permeability, that is, the ease with which air passes through the fabric Permeability measures fundamental fabric qualities and characteristics such as filtration and cover.

Yarn bloom is a measure of the opening and spread of fibers in yarn.

Fabric weight is measured in weight per unit area, for example, the number of ounces per square yard.

Torque of fabric refers to that characteristic which tends to make it turn on itself as a result of twisting It is desirable to remove or diminish torque in fabrics. For example, fabrics used in vertical blinds should have no torque, since such torque will make the fabric twist when hanging in a strip.

Wrinkle recovery is the property of a fabric which enables it to recover from folding deformations.

Hand refers to tactile fabric properties such as softness and drapability.

It is known in the prior art to employ hydroentangling processes in the production of nonwoven materials. In conventional hydroentangling processes, webs of nonwoven fibers are treated with high pressure fluids while supported on apertured patterning screens. Typically, the patterning screen is provided on a drum or continuous planar conveyor which traverses pressur-

ized fluid jets to entangle the web into cohesive ordered fiber groups and configurations corresponding to open areas in the screen. Entanglement is effected by action of the fluid jets which cause fibers in the web to migrate to open areas in the screen, entangle and intertwine.

Prior art hydroentangling processes for producing patterned nonwoven fabrics are represented by U.S. Pat. Nos. 3,485,706 and 3,498,874, respectively, to Evans and Evans et al., and U.S. Pat. Nos. 3,873,255 and 3,917,785 to Kalwaites.

Hydroentangling technology has also been employed by the art to enhance woven and knit fabrics. In such applications warp and pick fibers in fabrics are hydroentangled at crossover points to effect enhancement in fabric cover. However, conventional processes have not proved entirely satisfactory in yielding uniform fabric enhancement. The art has also failed to develop apparatus and process line technology which achieves production line efficiencies.

Australian Patent Specification 287821 to Bunting et al. is representative of the state of the art. Bunting impacts high speed columnar fluid streams on fabrics supported on course porous members. Preferred parameters employed in the Bunting process, described in the Specification Example Nos. XV–XVII, include 20 and 30 mesh support screens, fluid pressure of 1500 psi, and jet orifices having 0.007 inch diameters on 0.050 inch centers. Fabrics are processed employing multiple hydroentangling passes in which the fabric is reoriented on a bias direction with respect to the process direction in order to effect uniform entanglement. Data set forth in the Examples evidences a modest enhancement in fabric cover and stability.

Another approach of art is represented by European Patent Application No. 0 177 277 to Willbanks et al. which is directed to hydropatterning technology. Willbanks impinges high velocity fluids onto woven, knitted and bonded fabrics for decorative effects. Patterning is effected by redistributing yarn tension within the fabric - yarns are selectively compacted, loosened and opened - to impart relief structure to the fabric.

Fabric enhancement of limited extent is obtained in Willbanks as a secondary product of the patterning process. However, Gilpatrick fails to suggest or teach a hydroentangling process that can be employed to uniformly enhance fabric characteristics. See Willbanks Example 4, page 40.

There is a need in the art for an improved woven textile hydroenhancing process which is commercially viable. It will be appreciated that fabric enhancement offers aesthetic and functional advantages which have application in a wide diversity of fabrics. Hydroenhancement improves fabric cover through dynamic fluid entanglement and bulking of fabric yarns for improved fabric stability. These results are advantageously obtained without requirement of conventional fabric finishing processes.

The art also requires apparatus of uncomplex design for hydroenhancing textile materials. Commercial production requires apparatus for continuous fabric hydroenhancing and in-line drying of such fabrics under controlled conditions to yield fabrics of uniform specifications.

Accordingly, it is a broad object of the invention to provide an improved textile hydroenhancing process and related apparatus for production of a variety of

novel woven and knit fabrics having improved characteristics which advance the art.

A more specific object of the invention is to provide a hydroenhancing process for enhancement of fabrics made of spun and spun/filament yarn.

Another object of the invention is to provide a hydroenhancing process having application for the fabrication of novel composite and layered fabrics.

A further object of the invention is to provide a hydroenhancing production line apparatus which is less complex and improved over the prior art.

DISCLOSURE OF THE INVENTION

In the present invention, these purposes, as well as others which will be apparent, are achieved generally by providing an apparatus and a related method for hydroenhancing woven and knit fabrics through dynamic fluid action. A hydroenhancing module is employed in the invention in which the fabric is supported on a member and impacted with a fluid curtain under controlled process energies. Enhancement of the fabric is effected by entanglement and intertwining of yarn fibers at cross-over points in the fabric weave or knit. Fabrics enhanced in accordance with the invention have a uniform finish and improved characteristics, such as, edge fray, drape, stability, wrinkle recovery, abrasion resistance, fabric weight and thickness.

According to the preferred method of the invention, the woven or knit fabric is advanced on a process line through a weft straightener to two in-line fluid modules for first and second stage fabric enhancement. Top and bottom sides of the fabric are respectively supported on members in the modules and impacted by fluid curtains to impart a uniform finish to the fabric. Preferred support members are fluid pervious, include open areas of approximately 25%, and have fine mesh patterns which permit fluid passage without imparting a patterned effect to the fabric. It is a feature of the invention to employ support members in the modules which include fine mesh patterned screens which are arranged in offset relation with respect to the process line. This offset orientation limits fluid streaks and eliminates reed marking in processed fabrics.

First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.

Following enhancement, the fabric is advanced to a tenter frame which dries the fabric to a specified width under tension to produce a uniform fabric finish.

Advantage in the invention apparatus is obtained by provision of a continuous process line of uncomplex design. The first and second enhancement stations include a plurality of cross-directionally ("CD") aligned and spaced manifolds. Columnar jet nozzles having orifice diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches are mounted approximately 0.5 inches from the screens. At the process energies of the invention, this spacing arrangement provides a curtain of fluid which yields a uniform fabric enhancement. Use of fluid pervious support members which are oriented in offset relation, preferably 45°, effectively limits jet streaks and eliminates reed markings in processed fabrics.

Optimum fabric enhancement results are obtained in fabrics woven or knit of yarns including fibers with deniers and staple lengths in the range of 0.5 to 6.0, and

0.5 to 5 inches, respectively, and yarn counts in the range of 0.5s to 50s. Preferred yarn spinning systems of the invention fabrics include cotton spun, wrap spun, wool spun and friction spun.

Other objects, features and advantages of the present invention will be apparent when the detailed description of the preferred embodiments of the invention are considered in conjunction with the drawings which should be construed in an illustrative and not limiting sense as follows:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a production line including a weft straightener, flat and drum hydroenhancing modules, and tenter frame, for the hydroenhancement of woven and knit fabrics in accordance with the invention;

FIGS. 2A and B are photographs at 10× magnification of 36×29 90° and 40×40 45° mesh plain weave support members, respectively, employed in the flat and drum enhancing modules of FIG. 1;

FIGS. 3A and B are photomicrographs at 10× magnification of a fine polyester woven fabric before and after hydroenhancement in accordance with the invention;

FIGS. 4A and B are photomicrographs at 16× magnification of the control and processed fabric of FIGS. 3A and B;

FIGS. 5A and B are photomicrographs at 10× magnification of a control and hydroenhanced woven acrylic fabric;

FIGS. 6A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 7A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 8A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric including open end wool spun yarn;

FIGS. 9A and B are photomicrographs at 16× magnification of a control and hydroenhanced wool nylon (80/20%) fabric;

FIGS. 10A and B are photomicrographs at 16× magnification of a control and hydroenhanced spun/filament polyester/cotton twill fabric;

FIGS. 11A and B are photomicrographs at 16× magnification of a control and hydroenhanced doubleknit fabric;

FIGS. 12A and B are front and back side photomicrographs at 16× magnification of a control wall covering fabric;

FIGS. 13A and B are front and back side photomicrographs at 16× magnification of the wall covering fabric of FIGS. 12A and B hydroenhanced in accordance with the invention;

FIG. 14 is a photomacrograph at 0.09× magnification of a control and hydroenhanced acrylic fabric strips, the fabric of FIGS. 7A and B, showing the reduction in fabric torque achieved in the invention process;

FIGS. 15 A–C are photomacrographs at 0.23× magnification, respectively, of the woven acrylic fabrics of FIGS. 5, 7 and 8, comprised of wrap spun and open end wool spun yarns, showing washability and wrinkle characteristics of control and processed fabrics;

FIG. 16 is a schematic view of an alternative production line apparatus for the hydroenhancement of woven and knit fabrics in accordance with the invention; and

FIG. 17 illustrates a composite fabric including napped fabric components which are bonded into an integral structure employing the hydroenhancing process of the invention.

BEST MODE OF CARRYING OUT THE INVENTION

With further reference to the drawings, FIG. 1 illustrates a preferred embodiment of a production line of the invention, generally designated 10, for hydroenhancement of a fabric 12 including spun and/or spun/-filament yarns. The line includes a conventional weft straightener 14, flat and drum enhancing modules 16, 18, and a tenter frame 20.

Modules 16, 18 effect two sided enhancement of the fabric through fluid entanglement and bulking of fabric yarns. Such entanglement is imparted to the fabric in areas of yarn crossover or intersection. Control of process energies and provision of a uniform curtain of fluid produces fabrics having a uniform finish and improved characteristics including, edge fray, torque, wrinkle recovery, cupping, drape, stability, abrasion resistance, fabric weight and thickness.

METHOD AND MECHANISM OF THE ENHANCING MODULES

Fabric is advanced through the weft straightener 14 which aligns the fabric weft prior to processing in enhancement modules 16, 18. Following hydroenhancement, the fabric is advanced to the tenter frame 20, which is of conventional design, where it is dried under tension to produce a uniform fabric of specified width.

Module 16 includes a first support member 22 which is supported on an endless conveyor means including rollers 24 and drive means (not shown) for rotation of the rollers. Preferred line speeds for the conveyor are in the range of 10 to 500 ft/min. Line speeds are adjusted in accordance with process energy requirements which vary as a function of fabric type and weight.

Support member 22, which preferably has a flat configuration, includes closely spaced fluid pervious open areas 26. A preferred support member 22, shown in FIG. 2A, is a 36×29 90° mesh plain weave having a 23.7% open area, fabricated of polyester warp and shute round wire. Support member 22 is a tight seamless weave which is not subject to angular displacement or snag. Specifications for the screen, which is manufactured by Albany International, Appleton Wire Division, P.O. Box 1939, Appleton, Wis. 54913 are set forth in Table I.

TABLE I

Property	Support Screen Specifications	
	36 × 29 90° flat mesh	40 × 40 45° drum mesh
Wire	polyester	stainless steel
Warp wire	.0157	0.010
Shute wire	.0157	0.010
Weave type	plain	plain
Open area	23.7%	36%

Module 16 also includes an arrangement of parallel and spaced manifolds 30 oriented in a cross-direction ("CD") relative to movement of the fabric 12. The manifolds which are spaced approximately 8 inches apart each include a plurality of closely aligned and spaced columnar jet orifices 32 which are spaced approximately 0.5 inches from the support member 22.

The jet orifices have diameters and center-to-center spacings in the range of 0.005 to 0.010 inches and 0.017 to 0.034 inches, respectively, and are designed to impact the fabric with fluid pressures in the range of 200 to 3000 psi. Preferred orifices have diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches.

This arrangement of fluid jets provides a curtain of fluid entangling streams which yield optimum enhancement in the fabric. Energy input to the fabric is cumulative along the line and preferably set at approximately the same level in modules 16, 18 (two stage system) to impart uniform enhancement to top and bottom surfaces of the fabric. Effective first stage enhancement of fabric yarn is achieved at an energy output of at least 0.05 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb.

Following the first stage enhancement, the fabric is advanced to module 18 which enhances the other side of the fabric. Module 18 includes a second support member 34 of cylindrical configuration which is supported on a drum. The member 34 includes closely spaced fluid pervious open areas 36 which comprise approximately 36% of the screen area. A preferred support member 34, shown in FIG. 2B, is a 40×40 45° mesh stainless steel screen, manufactured by Appleton Wire, having the specifications set forth in Table I.

Module 18 functions in the same manner as the planar module 16. Manifolds 30 and jet orifices 32 are provided which have substantially the same specifications as in the first stage enhancement module. Fluid energy to the fabric of at least 0.5 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb effects second stage enhancement.

Conventional weaving processes impart reed marks to fabrics. Illustrations of such markings are shown in FIGS. 3A and 4A which are photomicrographs at 10× and 16× magnification of a polyester LIBBEY brand fabric style no. S/x-A805 (see Table II). Reed marks in FIGS. 3A and 4A are designated by the letter "R".

The invention overcomes this defect in conventional weaving processes through use of a single and preferably two stage hydroenhancement process. Advantage is obtained in the invention process by orienting the drum support member 34 in offset relation, preferably 45°, relative to machine direction ("MD") of the hydroenhancing line. See FIGS. 2A and B.

Support members 22 and 34 are preferably provided with fine mesh open areas which are dimensioned to effect fluid passage through the members without imparting a patterned effect to the fabric. The preferred members have an effective open area for fluid passage in the range of 17–40%.

Comparison of the control and processed polyester fabric of FIGS. 3A, B and 4A, B illustrates the advantages obtained through use of the enhancement process. Reed marks R in control polyester fabric are essentially eliminated through enhancement of the fabric. The offset screen arrangement is also effective in diminishing linear jet streak markings associated with the enhancement process.

EXAMPLES I–XIII

FIGS. 3–15 illustrate representative woven and knit fabrics enhanced in accordance with the method of the invention, employing test conditions which simulate the line of FIG. 1. Table II sets forth specifications for the fabrics illustrated in the drawings.

As in the FIG. 1 line, the test manifolds 30 were spaced approximately 8 inches apart in modules 16, 18,

and provided with densely packed columnar jet orifices 32 of approximately 60/inch. Orifices 32 each had a diameter of 0.005 inches and were spaced approximately 0.5 inches from the first and second support members 22, 34.

The process line of FIG. 1 includes enhancement modules 16, 18 which, respectively, are provided with six manifolds. In the Examples, modules 16, 18 were each fitted with two manifolds 34. To simulate line conditions, the fabrics were advanced through multiple runs on the line. Three processing runs in each two manifold module was deemed to be equivalent to a six manifold module.

Fabrics were hydroenhanced at process pressures of approximately 1500 psi. Line speed and cumulative energy output to the modules were respectively maintained at approximately 30 fpm and 0.46 hp-hr/lb. Adjustments in the line speed and fluid pressure were made to accommodate differences in fabric weight for uniform processing and to maintain the preferred energy level.

Fabrics processed in the Examples exhibited marked enhancement in aesthetic appearance and quality including, characteristics such as cover, bloom, abrasion resistance, drape, stability, and reduction in seam slippage, and edge fray.

Tables III–XI set forth data for fabrics enhanced in accordance with invention on the test process line. Standard testing procedures of The American Society for Testing and Materials (ASTM) were employed to test control and processed characteristics of fabrics. Data set forth in the Tables was generated in accordance with the following ASTM standards:

Fabric Characteristic	ASTM Standard
Weight	D3776-79
Thickness	D1777-64 (Ames Tester)
Tensile Load	D1682-64 (1975) (Cut strip/grab)
Elongation	D1682-64 (1975)
Air Permeability	D737-75 (1980) (Frazier)
Threa Count	D3775-79
Ball Burst	D3787-80A
Seam Slippage	D4159-82
Tongue Tear	D2261-71
Wrinkle Recovery	D1295-67 (1972)
Abrasion Resistance	D3884-80
Pilling	D3514-81

Washability tests were conducted in accordance with the following procedure. Weight measurements ("before wash") were taken of control and processed fabric samples each having a dimension of 8.5×11" (8.5" fill direction and 11" warp direction). The samples were then washed and dried in conventional washer and dryers three consecutive times and "after wash" measurements were taken. The percent weight loss of the pre and post wash samples was determined in accordance the following formula:

$$\%\ \text{weight loss} = D/B \times 100$$

where, B=before wash sample weight; A=after wash sample weight; and D=B−A.

Photomicrographs of the fabrics, FIGS. 4–15, illustrate the enhancement in fabric cover obtained in the invention. Attention is directed to open areas in the unprocessed fabrics, photographs designated A, these areas are of reduced size in the processed fabrics in the photographs designated B. Hydroenhancement caused fabric yarns to bloom and entangle at cross-over points, filling in open areas to improve cover and reduce air permeability in the fabrics.

FIGS. 12 and 13 are photomicrographs of a HYTEX brand wall covering fabric, manufactured by Hytex, Inc, Randolph, Mass. A multi-textured surface appearance of the fabric is provided by yarns which are woven through discrete areas of the front fabric surface. Free floating weave stitches, designated by the letter "S" in FIGS. 12B and 13B, are formed on the backside of the fabric.

Hydroenhancement of HYTEX wall covering fabric secured the free-floating stitches S to the fabric backside enhancing fabric stability and cover. See FIGS. 12B, 13B. In wall covering applications, fabric enhancement and associated stabilizing effects reduces or eliminates the need for adhesive backcoatings. Enhancement of the fabric also limits wicking of wall cover application adhesives through the fabric. Further advantage is obtained when enhanced fabrics are used in acoustic applications; elimination of backcoating reduces sound reflection and furthers efficient transmission of sound through the fabric.

TABLE II

Fabric Specifications Fiber Brand and Style Designation	Figure (s)
NOMEX S/x-A805* Fiber: 2 denier-1.9 inch Yarn: Open end cotton spun 17s	3 A,B, 4 A,B
LIBBEY S/022** Warp: Fiber: 3 denier - 1.5 inch acrylic Yarn: Open end cotton spun 9s 28 ends per inch Fill: Fiber: 3 denier - 3 inch acrylic Yarn: Open end wool spun 4s 14, 16 or 18 picks per inch	5 A,B
LIBBEY S/x-1160 Fiber: 3 denier-3 inch acrylic Yarn: Wrap spun w/100 den textured polyester 4s 14 ends × 16 picks per inch	6 A,B
LIBBEY S/406 Warp: Fiber: 3 denier - 1.5 inch acrylic Yarn: Open end cotton spun 9s 28 ends per inch Fill: Fiber: 3 denier - 3 inch acrylic Yarn: Hollow spun 6 twists/inch 4s 14, 16 or 18 picks per inch	7 A,B, 14 A,B
LIBBEY S/152 Warp: Fiber: 3 denier - 2.5 inch acrylic Yarn: Open end cotton spun 4s 14 ends per inch Fill: Fiber: 3 denier - 3 inch acrylic Yarn: Open end wool spun 2.6s 14, 16 or 18 picks per inch	8 A,B
Guilford Wool/Nylon 80% wool/20% nylon	9 A,B
Polyester/cotton (53/47) Weight: 10 ounces/yd^2 Yarn: Spun Filament Weave: 3 × 1 Twill Thread Count: 120 × 38	10 A,B
50% Polyester/50% cotton Doubleknit Yarn: wrap spun with 100 denier polyester wrap	11 A,B

TABLE II-continued

Fabric Specifications	
Fiber Brand and Style Designation	Figure (s)
HYTEX Wall covering***	12, 13

*LIBBEY is a trademark of W.S. Libbey Co., One Mill Street, Lewiston, ME 04240.
**NOMEX is a trademark of E.I. Du Pont de Nemours and Company, Wilmington, Del.
***HYTEX is a trademark of Hytex, Inc., Randolph, MA.

TABLE III

Nomex A805 - FIG. 4	Control	Processed	% Chance
Weight (gsy)	195	197	+1.0
Thickness (mils)	42	42	0
Air Perm. (ft^3/ft^2/min)	331	156	−52.9
Strip Tensile (lbs/in)			
warp	115	132	+14.8
fill	59	47	−20.3
Elongation %			
warp	48	50	+4.2
fill	62	71	+14.5

TABLE IV

022/6075 (16 ppi) - FIG. 5	Control	Processed	% Change
Weight (gsy)	158	165	+4.4
Thickness (mils)	48	49	+2.1
Air Perm. (ft^3/ft^2 min)	406	259	−36.2
Strip Tensile (lbs/in)			
warp	34	36	+5.9
fill	37	31	−16.2
Elongation (%)			
warp	33	27	−18.2
fill	27	28	+3.7
Seam Slippage (lbs/in)			
warp	5	60	+1100.0
fill	7	55	+685.7
Tongue Tear (lbs)			
warp	18	10	−44.4
fill	21	8	−61.9
Wt. Loss In Wash (%)	37	5	−86.5
Wrinkle Recovery* (recovery angle)	123°	138°	+12.2

*Under ASTM test standards (D1295-67) improvements in the wrinkle recovery of a fabric are indicated by an increase in the recovery angle.

TABLE V

LIBBEY S/x-1160 - FIG. 6	Control	Processed	% Change
Weight (gsy)	146.8	160.2	9.1
Thickness (mils)	38.1	52.7	38.3
Air Perm. (ft^3/ft^2 min)	457.2	188.5	−58.8
Grab Tensile (lbs/in)			
warp	80.2	89.3	11.4
fill	105.0	111.4	6.1
Elongation (%)			

TABLE V-continued

LIBBEY S/x-1160 - FIG. 6	Control	Processed	% Change
warp	30.0	34.0	13.3
fill	32.0	46.0	43.8
Ball Burst (lbs)	190	157	−17.4

TABLE VI

406/6075 (16 ppi) - FIG. 7	Control	Processed	% Change
Weight (gsy)	159	166	+4.4
Thickness (mils)	48	50	+4.2
Air Perm. (ft^3/ft^2 min)	351	184	−47.6
Strip Tensile (lbs/in)			
warp	42	36	−14.3
fill	66	58	−12.1
Elongation (%)			
warp	23	31	+34.8
fill	49	33	−32.7
Seam Slippage (lbs)			
warp	29	36	+89.5
fill	21	76	+261.9
Tongue Tear (lbs)			
warp	23	18	−21.7
fill	19	15	−1.1
Wt. Loss In Wash (%)	28	4	−85.7
Wrinkle Recovery (recovery angle)	140°	148°	+5.7

TABLE VII

152/6076 (16 ppi) - FIG. 8	Control	Processed	% Change
Weight (gsy)	231	257	+11.3
Thickness (mils)	259	238	−8.1
Air Perm. (ft^3/ft^2/min)	204	106	−48.0
Strip Tensile (lbs/in)			
warp	48	58	+20.8
fill	56	72	+28.6
Elongation (%)			
warp	33	33	0
fill	34	39	+14.7
Seam Slippage (lbs)			
warp	64	81	+26.6
fill	78	112	+43.6
Tongue Tear (lbs)			
warp	21	18	−14.3
fill	17	15	−11.8
Wt. Loss In Wash (%)	—	—	—
Wrinkle Recovery (recovery angle)	117°	136°	+16.2

TABLE VIII

Guilford Wool (80% wool/20% nylon) - FIG. 9	Control	Process	% Change
Air Perm.	243	147	−39.5

TABLE IXA

Spun/Filament - Bottom Weights - FIG. 10	Sample #1		Sample #2		Sample #3		Sample #4	
	Control	Proc	Control	Proc	Control	Proc	Control	Proc
Weight (gsy)	259.2	275.4	240.3	248.4	286.2	297.2	267.3	280.8
Thickness (mils)	39.7	39.2	35.0	35.3	44.2	41.5	40.0	38.0
Strip Tensiles (lbs./in.)								
Warp	206.98	208.87	195.50	200.86	183.09	189.95	206.43	207.87
Fill	85.55	56.23	84.21	71.83	80.88	83.01	80.16	82.14
Normalized Tensiles								

TABLE IXA-continued

	Spun/Filament - Bottom Weights - FIG. 10							
	Sample #1		Sample #2		Sample #3		Sample #4	
	Control	Proc	Control	Proc	Control	Proc	Control	Proc
(lbs./in.)								
Warp	7.98	7.58	8.05	8.09	6.40	6.39	7.65	7.40
Fill	3.30	2.04	3.54	2.89	2.83	2.79	3.03	2.93
Elongation (%)								
Warp	42.0	55.3	36.5	39.1	40.9	43.5	46.1	51.2
Fill	23.6	25.6	24.0	20.0	23.5	20.3	22.9	22.4
Air Perm. ($ft.^3/ft.^2/min$)	50.9	27.3	43.5	28.8	45.8	21.8	51.4	25.4
Thread Count (wxf)	120 × 40	120 × 41	120 × 45	120 × 45	120 × 38	120 × 42	120 × 42	120 × 43
Mullen Burst (lbs.)	161.2	222.2	187.2	228.8	161.0	217.8	205.0	242.2
Normalized Burst ($lbs./g \times 10^2$)	62.2	80.7	77.9	92.1	56.2	73.3	76.7	86.3

TABLE IXB

Abrasion - Spun Filament-Bottom Weights - FIG. 10
ASTM Standard - Twill side up; 500 cycles;
500 g weight; H-18 wheels

Sample	Weight Before (g)	Weight After (g)	Weight Loss (g)	% Loss	% Improvement
1C	3.32	3.02	0.30	9.0	23%
1P	3.36	3.13	0.23	6.9	
2C	4.64	4.16	0.48	10.4	48%
2P	4.83	4.57	0.26	5.4	
3C	4.73	4.47	0.26	5.5	18%
3P	4.91	5.13	0.22	4.5	
4C	4.47	4.18	0.29	6.5	41%
4P	4.71	4.53	0.18	3.8	

TABLE X

	Doubleknit - FIG. 11		
	Control	Processed	% Change
Air Perm. (Ft^3/ft^2 min)	113.1	95.1	−15.9
Abrasion	1.0	0.6	−40.0
ASTM (D-3884-80): 250 Cycles, H-18 wheel			
Pilling (1-5 rating)	4.3	4.3	0
ASTM (D-3914-81): 300 cycles			

FIGS. 14A, B are photomacrographs of control and processed acrylic vertical blind fabric, manufactured by W. S. Libbey, style designation S/406. Enhancement of the fabric reduces fabric torque which is particularly advantageous in vertical blind applications. The torque reduction test of FIGS. 14A, B employed fabric strips 84" long and 3.5" wide, which were suspended vertically without restraint. Torque was measured with reference to the angle of fabric twist from a flat support surface. As can be seen in the photographs, a torque of 90° in the unprocessed fabric, FIG. 14A, was eliminated in the enhancement process.

FIGS. 15A–C are macrophotographs of control and processed acrylic fabrics, LIBBEY style nos. 022, 406 and 152, respectively, which were tested for washability. Unprocessed fabrics exhibited excessive fraying and destruction, in contrast to the enhanced fabrics which exhibit limited fraying and yarn (weight) loss. Table XI sets forth washability test weight loss data.

TABLE XI

022, 406, 152 - FIGS. 15 A-C
Percent Weight Loss
(3 wash/dry cycles)

Sample	Control	Processed
022	36.5	5.0
406	28.0	4.0

TABLE XI-continued

022, 406, 152 - FIGS. 15 A-C
Percent Weight Loss
(3 wash/dry cycles)

Sample	Control	Processed
152	28.1	7.2

FIG. 16 illustrates an alternative embodiment of the invention apparatus, generally designated **40**. The apparatus includes a plurality of drums **42*a–d*** over which a fabric **44** is advanced for enhancement processing. Specifically, the fabric **44** traverses the line in a sinuous path under and over the drums **42** in succession. Rollers **46*a*** and ***b*** are provided at opposite ends of the line adjacent drums **42*a*** and ***d*** to support the fabric. Any or all of the drums can be rotated by a suitable motor drive (not shown) to advance the fabric on the line.

A plurality of manifolds **48** are provided in groups, FIG. **16** illustrates groups of four, which are respectively spaced from each of the drums **42*a–d***. An arrangement of manifold groups at 90° intervals on the sinuous fabric path successively positions the manifolds in spaced relation with respect to opposing surfaces of the fabric. Each manifold **48** impinges columnar fluid jets **50**, such as water, against the fabric. Fluid supply **52** supplies fluid to the manifolds **48** which is collected in liquid sump **54** during processing for recirculation via line **56** to the manifolds.

The support drums **42** may be porous or non-porous. It will be recognized that advantage is obtained through use of drums which include perforated support surfaces. Open areas in the support surfaces facilitate recirculation of the fluid employed in the enhancement process.

Further advantage is obtained, as previously set forth in discussion of the first embodiment, through use of support surfaces having a fine mesh open area pattern which facilitates fluid passage. Offset arrangement of the support member orientations, for example at 45° offset orientation as shown in FIG. 2, limits process water streak and weave reed marks in the enhanced fabric.

Enhancement is a function of energy which is imparted to the fabric. Preferred energy levels for enhancement in accordance with the invention are in the range of 0.1 to 2.0 hp-hr/lb. Variables which determine process energy levels include line speed, the amount and velocity of liquid which impinges on the fabric, and fabric weight and characteristics.

Fluid velocity and pressure are determined in part by the characteristics of the fluid orifices, for example,

columnar versus fan jet configuration, and arrangement and spacing from the process line. It is a feature of the invention to impinge a curtain of fluid on a process line to impart an energy flux of approximately 0.46 hp-hr/lb to the fabric. Preferred specifications for orifice type and arrangement are set forth in description of the embodiment of FIG. 1. Briefly, orifices **16** are closely spaced with center-to-center spacings of approximately 0.017 inches and are spaced 0.5 inches from the support members. Orifice diameters of 0.005 inches and densities of 60 per manifold inch eject columnar fluid jets which form a uniform fluid curtain.

The following Examples are representative of the results obtained on the process line illustrated in FIG. 17.

EXAMPLE XIV

A plain woven 100% polyester fabric comprised of friction spun yarns having the following specifications was processed in accordance with the invention: count of 16×10 yarns/in^2, weight of 8 ounces/yd^2, an abrasion resistance of 500 grams (measured by 50 cycles of a CS17 abrasion test wheel) and an air permeability of 465 ft^3/ft^2/min.

The fabric was processed on a test line to simulate a speed of 300 ft/min. on process apparatus including four drums **42** and eighteen nozzles **16** at a pressure of approximately 1500 psi. Energy output to fabric at these process parameters was approximately 0.46 hp-hr/lb. Table XII sets forth control and processed characteristics of the fabric.

TABLE XII

100% Polyester Friction Spun Fabric		
Fabric Characteristic	Control	Processed
Count (yarns/in.^{2})	16 × 10	17 × 10
Weight (ounces/yd.^{2})	8	8.2
Abrasion resistance (cycles)	50	85
Air permeability (ft^{3}ft^2/min.)	465	181

EXAMPLES XV AND XVI

The process conditions of Example XIV were employed to process a plain woven cotton osnaburg and plain woven polyester ring spun fabrics yielding the results set forth in Tables XIV and XV.

TABLE XV

Plain Woven Cotton Osnaburg		
Fabric Characteristic	Control	Processed
Count (yarns/in.^{2})	32 × 26	32 × 32
Abrasion resistance (cycles)	140	344
Air permeability (ft^{3}ft^2/min.)	710	120

TABLE XIV

Fabric Characteristic	Control	Processed
Count (yarns/in.^{2})	44 × 28	48 × 32
Abrasion resistance (cycles)	100	225
Air permeability (ft.^{3}/ft^2/min.)	252	63

Fabrics processed in Examples XIV–XVI are characterized by a substantial reduction in air permeability and increase in abrasion resistance. Process energy levels in these Examples were approximately 0.46 hp-hr/lb. It has been discovered that there is a correlation between process energy and enhancement. Increased energy levels yield optimum enhancement effects.

The foregoing Examples illustrate applications of the hydroenhancing process of the invention for upgrading the quality of single ply woven and knit fabrics.

In an alternative application of the hydroenhancing process of the invention, fabric strata are hydrobonded into integral composite fabric. FIG. 17 illustrates a composite flannel fabric **60** including fabric layers **62, 64.** Hydrobonding of the layers is effected by first napping opposing surfaces **62*a*, 64*a*** of each of the layers to raise surface fibers. The opposing surfaces **62*a*, 44*a*** are then arranged in overlying relation and processed on the production line of the invention. See FIGS. 1 and 16. Enhancement of the layers **62, 64** effects entanglement of fibers in the napped surfaces and bonding of the layers to form a integral composite fabric **60.** Exterior surfaces **62*b*, 64*b*** are also enhanced in the process yielding improvements in cover and quality in the composite fabric.

Napped surfaces **62*a*, 62*b*** are provided by use of conventional mechanical napping apparatus. Such apparatus include cylinders covered with metal points or teasel burrs which abrade fabric surfaces.

Advantageously, composite fabric **60** is manufactured without requirement of conventional laminating adhesives. As a result, the composite fabric breaths and has improved tactile characteristics than obtained in prior art laminated composites. It will be recognized that such composite fabrics have diverse applications in fields such as apparel and footwear.

Optimum enhancement (in single and multi-ply fabrics) is a function of energy. Preferred results are obtained at energy levels of approximately 0.46 hp-hr/lb. Energy requirements will of course vary for different fabrics as will process conditions required to achieve optimum energy levels. In general, process speeds, nozzle configuration and spacing may be varied to obtain preferred process energy levels.

Enhanced fabrics of the invention are preferably fabricated of yarns including fibers having deniers and lengths, respectively, in the ranges of 0.3 to 10.0 and 0.5 to 6.0 inches, and yarn counts of 0.5s to 80s. Optimum enhancement is obtained in fabrics having fiber deniers in the range of 0.5 to 6, staple fibers of 0.5 to 6.0 inches, and yarn counts in the range of 0.5s to 50s. Preferred yarn spinning systems employed in the invention fabrics include cotton spun, wrap spun and wool spun. Experimentation indicates that preferred enhancement results are obtained in fabrics including low denier, short lengths fibers, and loosely twisted yarns.

The invention advances the art by recognizing that superior fabric enhancement can be obtained under controlled process conditions and energy levels. Heretofore, the art has not recognized the advantages and the extent to which hydroenhancement can be employed to upgrade fabric quality. It is submitted that the results achieved in the invention reflect a substantial and surprising contribution to the art.

Numerous modifications are possible in light of the above disclosure. For example, although the preferred process and apparatus employ fluid pervious support members, non-porous support members are within the scope of the invention. Similarly, FIGS. 1 and 16 respectively illustrate two and four stage enhancement process lines. System configurations which include one or more modules having flat, drum or other support member configuration may be employed in the invention.

It will be recognized that the process of the invention has wide application for the production of a diversity of enhanced fabrics. Thus, the Examples are not intended to limit the invention.

Finally, although the disclosed enhancement process employs columnar jet orifices to provide a fluid curtain, other apparatus may be employed for this purpose. Attention is directed to the International Patent Application (RO/US) to Siegel et al., entitled "Apparatus and Method For Hydropatterning Fabric", filed concurrently herewith, assigned to Veratec, Inc., which discloses a divergent jet fluid entangling apparatus for use in hydropatterning woven and nonwoven textile fabrics.

Therefore, although the invention has been described with reference to certain preferred embodiments, it will be appreciated that other hydroentangling apparatus and processes may be devised, which are nevertheless within the scope and spirit of the invention as defined in the claims appended hereto.

We claim:

1. A method for enhancing and finishing textile fabrics including spun and/or spun filament yarns which intersect at cross-over points, and first and second sides, the fabric including yarn fibers having deniers and lengths in the range of 0.3 to 16.0 and 0.5 to 8 inches, respectively, and yarn counts in the range of 0.5s to 80s, the method comprising the steps of:

supporting the fabric on a first support member, and traversing the first side of said fabric with a first continuous curtain of fluid for sufficient duration to effect entanglement of said yarns at the cross-over points, thereby enhancing fabric cover and quality,

said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

2. The method of claim 1, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches, center-to-center spacing of approximately 0.017 inches, and spacing from said first support member of approximately 0.5 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi.

3. The method of claim 2, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

4. The method of claim 3, wherein said open areas occupy approximately 17 to 40% of said support member.

5. The method of claim 1, comprising the further steps of:

supporting said enhanced fabric on a second support member, and

traversing the second side of said enhanced fabric in a second enhancement stage with a second continuous fluid curtain for sufficient duration to further enhance fabric cover and provide a uniform fabric finish,

said second enhancement stage impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

6. The method of claim 5, wherein:

said first and second fluid curtains are provided by columnar fluid jets each having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid curtains are spaced approximately 0.5 inches from said first and second members, and said fluid jets impinge the fabric with fluids at a pressure of approximately 1500 psi,

said first and second support members each include a pattern of closely spaced fluid pervious open areas, respectively aligned in first and second directions, said open areas being dimensioned to effect fluid passage through said support members without imparting a patterned effect to the fabric.

7. The method of claim 6, wherein said open areas occupy approximately 17 to 40% of each of said first and second support members.

8. The method of claim 7, wherein said first and second support members respectively have flat and drum configurations.

9. The method of claim 8, wherein said first and second directions are offset approximately 45°.

10. The method of claim 7, wherein said first and second support members have drum configurations.

11. The method of claim 10, wherein said first and second directions are offset approximately 45°.

12. The method of claim 6, comprising the further step, following said second stage enhancement, of drying the enhanced fabric to a specified width under tension.

13. An enhanced textile fabric made by the method of claim 6, the fabric including yarn fibers having deniers and lengths in the range of 0.3 to 16 and 0.5 to 8 inches, respectively, and thread counts in the range of 0.5s to 80s, the yarn cross-over points in the fabric weave define interstitial open areas, wherein the process effects enhancement of the yarns in the interstitial open areas, thereby enhancing fabric cover.

14. An enhanced textile fabric made by the method of claim 6, the fabric including yarn fibers having deniers and lengths in the range of 0.5 to 6 and 0.5 to 8 inches, respectively, and thread counts in the range of 0.5s to 50s, the yarn cross-over points in the fabric weave define interstitial open areas, wherein the process effects enhancement of the yarns in the interstitial open areas, thereby enhancing fabric cover, and yields a reduction in fabric air permeability in the range of 10 to 90%.

15. An enhanced woven polyester fabric made by the method of claim 6, wherein the fabric includes 2 denier, 1.9 inch polyester fiber, open-end cotton spun yarn having a yarn number of 17s and count of 49×23 per inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

16. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch fiber, open-end cotton warp yarn having a yarn number of 9s, 28 ends per inch, and a 3 denier, 3 inch acrylic fiber, open-end wool spun fill yarn having a number of 4s, 16 picks per inch, and the process yields an approximate 36% reduction in air permeability in the fabric.

17. An enhanced acrylic wrap spun fabric made by the method of claim 6, wherein the fabric includes 3 denier, 3.0 inch acrylic fiber, wrap spun with 100 denier textured polyester yarn having a yarn number of 4s and count of 14×16 per inch, and the process yields an approximate 65% reduction in air permeability in the fabric.

18. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch acrylic fiber, open-end cotton spun warp yarn having a yarn number of 9s, 28 ends per inch, and a 3 denier, 3 inch acrylic fiber, hollow wrap spun fill yarn, 6 twists per inch having a number of 4s, 16 picks per

inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

19. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch acrylic fiber, open-end wool spun warp yarn having a yarn number of 4s, 14 ends per inch, and a 3 denier, 3 inch acrylic fiber, open-end wool spun fill yarn having a yarn number of 2.6s, 16 picks per inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

20. An enhanced woven fabric made by the method of claim 6, wherein the fabric includes 80% wool/20% nylon in a 2×1 twill weave, and the process yields an approximate 49.5% reduction in air permeability in the fabric.

21. An enhanced 53% polyester/47% cotton fabric made by the method of claim 6, wherein the fabric includes a 3×1 twill weave, a thread count of 120 ends×38 picks, and the process yields an approximate 50.6% reduction in air permeability in the fabric.

22. An enhanced 50% polyester/50% cotton doubleknit fabric made by the method of claim 6, wherein the fabric includes wrap spun yarn with 100 denier polyester wrap, and the process yields an approximate 16% reduction in air permeability in the fabric.

23. An enhanced woven or knit textile fabric which comprises: spun and/or spun filament yarns which intersect at cross-over points to define interstitial open areas, said yarns including fibers having deniers and lengths in the range of 0.3 to 16.0 and 0.5 to 8 inches, respectively, wherein said yarns are fluid entangled in said interstitial open areas by application of fluid energy in the range of 0.1 to 2.0 hp-hr/lb.

24. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is cotton spun.

25. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is wrap spun.

26. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is wool spun.

27. A method for hydrobonding woven or knit fabric materials to form a composite textile fabric, the fabric including spun and/or spun filament yarns in a structured pattern including yarns which intersect at cross-over points, the method comprising the steps of:

napping first and second surfaces of the fabric to raise surface fibers thereof,

arranging said first and second surfaces in opposing and overlying layered relation,

supporting the layered fabric on a support member, and

traversing one side of said layered fabric with a first continuous curtain of fluid for sufficient duration to effect entanglement of said raised surface fibers in said first and second surfaces,

said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

28. The method of claim 27, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid curtain impinging the fabric with fluids at pressure of approximately 1500 psi.

29. The method of claim 28, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

30. The method of claim 29 wherein said open areas occupy approximately 17 to 40% of said support member.

31. The method of claim 27, comprising the further steps of:

supporting said layered fabric on a second support member, and

traversing the other side of said layered fabric in a second entanglement stage with a second continuous fluid curtain to effect a uniform composite fabric bond and finish,

said second entanglement stage impacting the layered fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

32. The method of claim 31, wherein:

said first and second fluid curtains are provided by columnar fluid jets having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi,

said first and second support members each include a pattern of closely spaced fluid pervious open areas, respectively aligned in first and second directions, said open areas being dimensioned to effect fluid passage through said support members without imparting a patterned effect to the fabric.

33. An enhanced composite woven or knit textile fabric which comprises:

at least two fabric layers which each include spun and/or spun filament yarns in a structured pattern of yarns which intersect at cross-over points, said fabric layers including first and second napped surfaces which have raised surface fibers, said napped surfaces being arranged in overlying and opposed relation and bonded together by dynamic fluid energy through entanglement of said raised surface fibers in said first and second surfaces.

34. An apparatus for enhancing and finishing woven and knit fabric including spun and/or spun filament yarn by impacting the fabric with pressurized fluid jets, the fabric including yarns which intersect at cross-over points, and first and second sides, the apparatus comprising:

conveyor means for conveying the fabric in a machine direction ("MD") through a production line including a first enhancing station, said conveying means supporting a first support member which underlies the fabric in said enhancing station;

curtain means spaced from said first support member for directing a curtain of fluid onto the first side of the fabric, said curtain means including a plurality of densely spaced orifices which eject high pressure fluid jets;

said curtain means coacting with said first support member to entangle fabric yarns at the cross-over points, enhancing fabric cover and imparting a uniform finish to the fabric.

35. An apparatus as set forth in claim 34, wherein said fluid orifices have a columnar configuration, a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.17 inches, and impart energy to the fabric of approximately 0.1 to 2.0 hp-hr/lb.

36. An apparatus as set forth in claim 35, wherein said fluid jets have a spray pressure of approximately 1500 psi.

37. An apparatus as set forth in claim 34, further comprising a second enhancing station, a second sup-

port member which underlies the fabric and is supported for movement on the production line by said conveyor means, and a second curtain means spaced from said second support member for directing a curtain of fluid onto the second side of the fabric, said second curtain means including a second plurality of densely spaced orifices which eject high pressure fluid jets, thereby further enhancing the fabric.

38. An apparatus as set forth in claim 37, wherein said first and second fluid curtains respectively impart energy to the fabric of approximately 0.1 to 2.0 hp-hr/lb.

39. An apparatus as set forth in claim 38, wherein said second support member is fluid pervious and has open

areas aligned on a bias relative to the machine direction of the line.

40. An apparatus as set forth in claim 39, wherein said first and second curtain means are spaced approximately 0.5 inches from said first and second support members, said fluid jets have a spray pressure of approximately 1500 psi, and conveyor means speed is approximately 100 fpm.

41. An apparatus as set forth in claim 40, wherein said first and second support members respectively have generally flat and cylindrical configurations.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,967,456

DATED : November 6, 1990

INVENTOR(S) : Herschel Sternlieb, Jodie M. Siegel, John M. Greenway

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, under Related U.S. Application Data [63], "Continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned, which is a continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned.", should read -- Continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned, which is a continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned. --.

In the drawings, Sheets 1 - 17, "Figs. 1-17"' should be replaced by -- seventeen (17) sheets of Formal Drawings, Figs. 1-17 --, as shown on the attach pages.

Column 1, line 53 after "twisting" insert -- . --.

Column 2, line 45, "Gilpatrick", should read -- Willbanks --.

Signed and Sealed this

Twenty-seventh Day of October, 1992

Attest:

DOUGLAS B. COMER

Attesting Officer *Acting Commissioner of Patents and Trademarks*

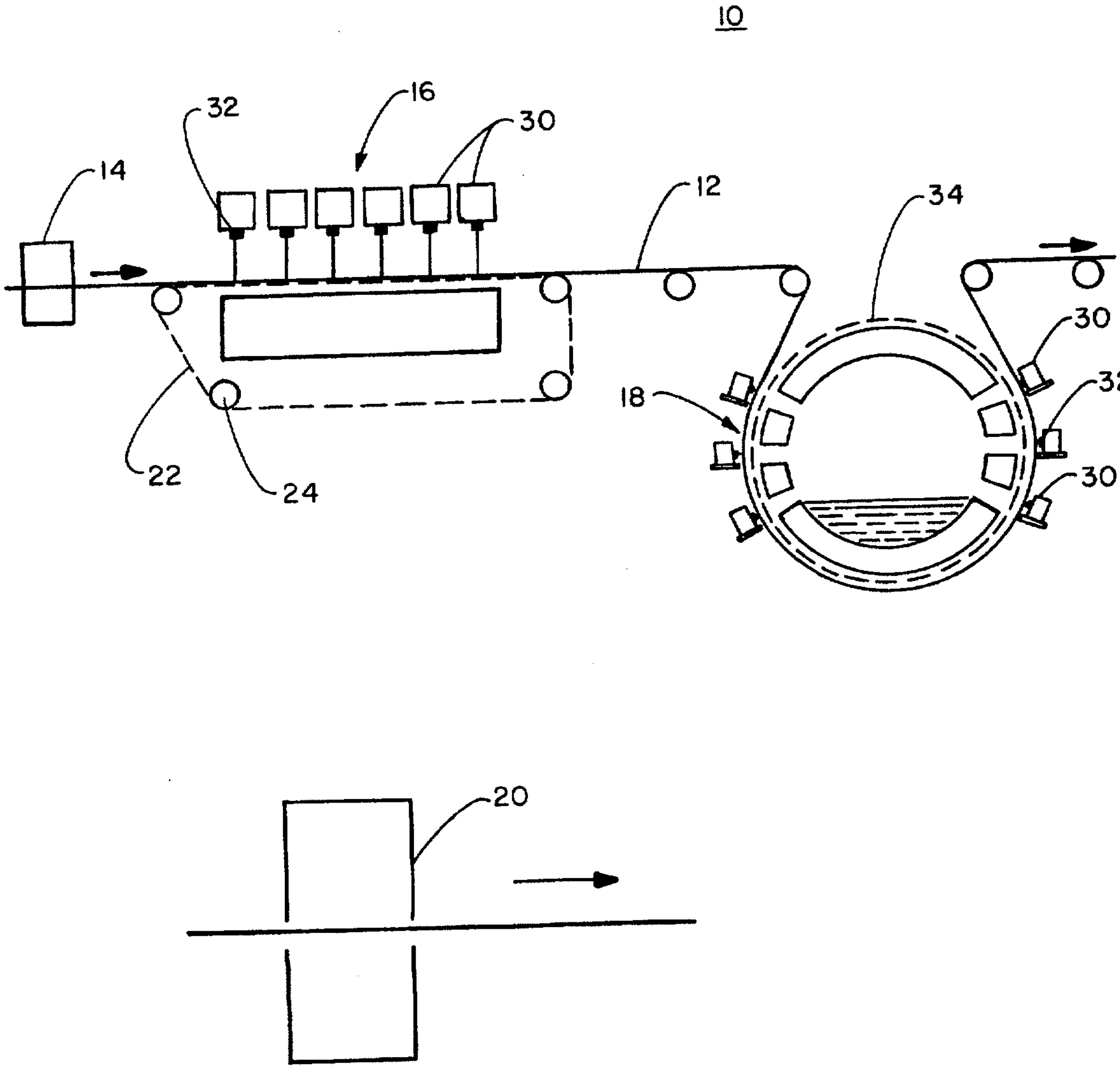


FIG. 1

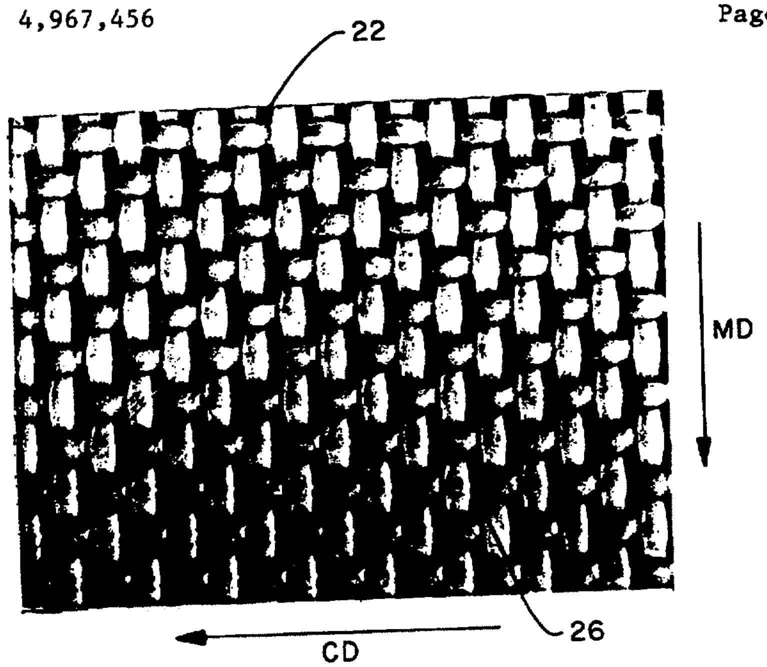


FIG. 2A

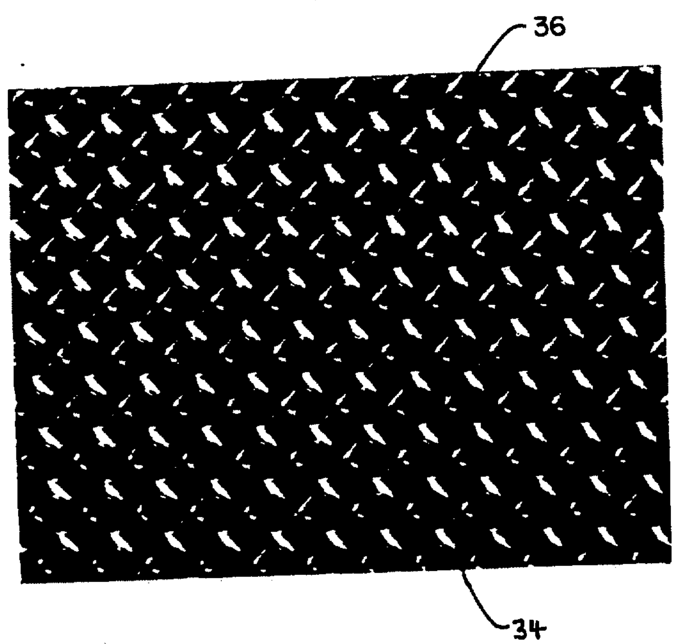


FIG. 2B

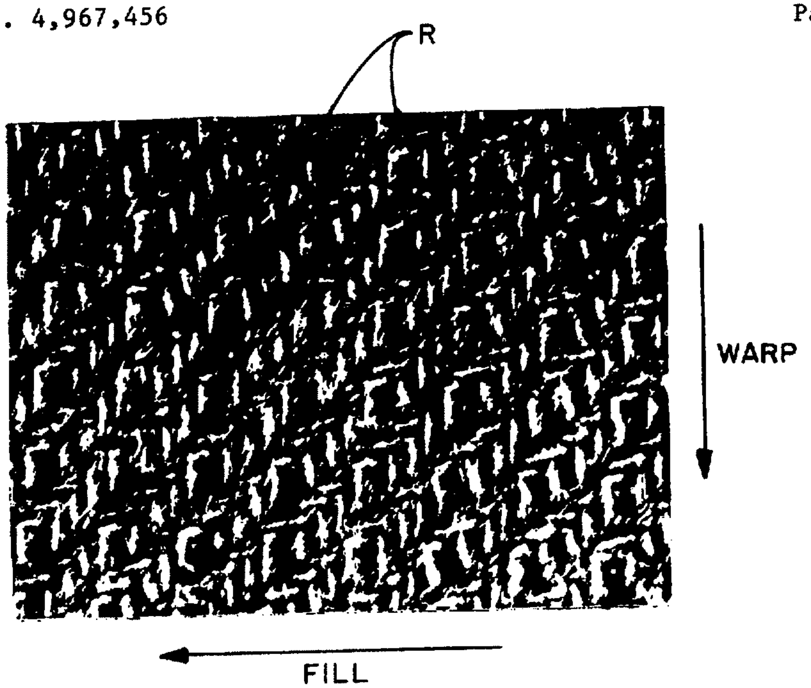


FIG. 3A

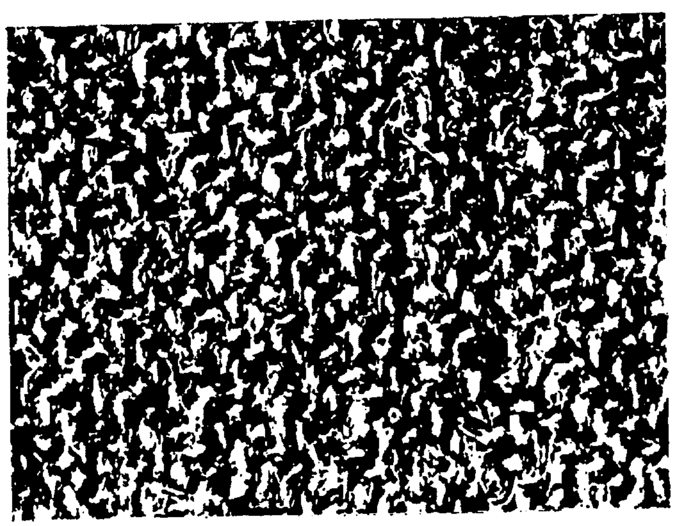


FIG. 3B

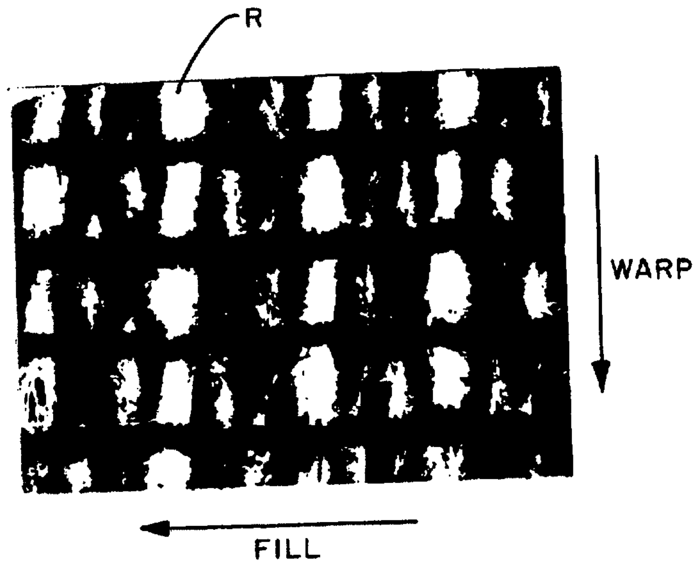


FIG. 4A

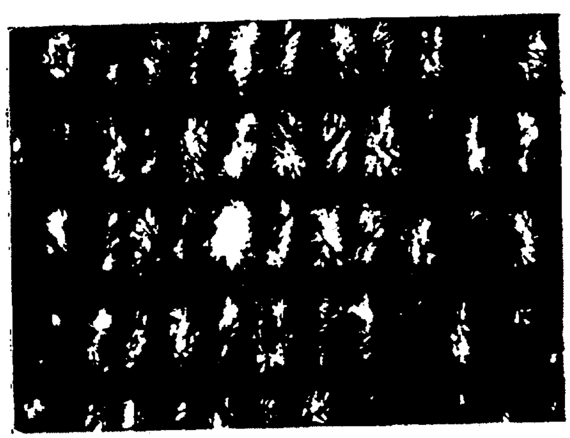


FIG. 4B

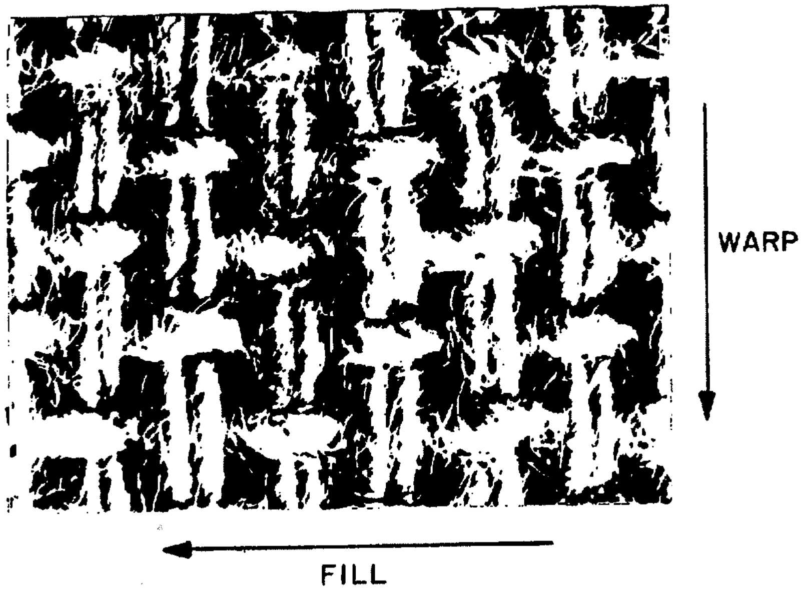


FIG. 5A

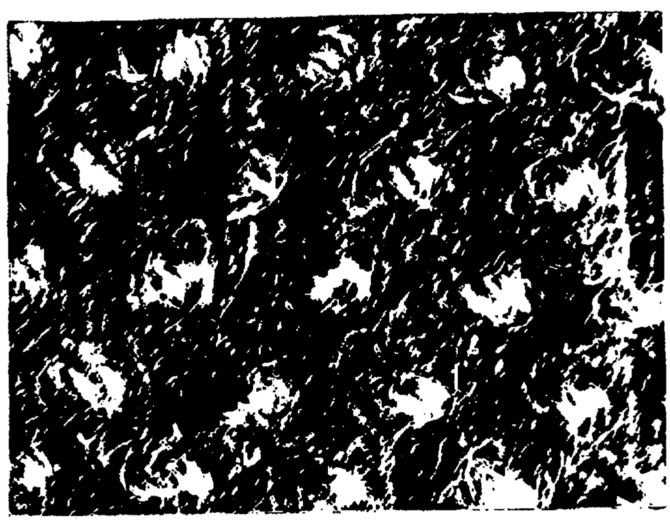


FIG. 5B

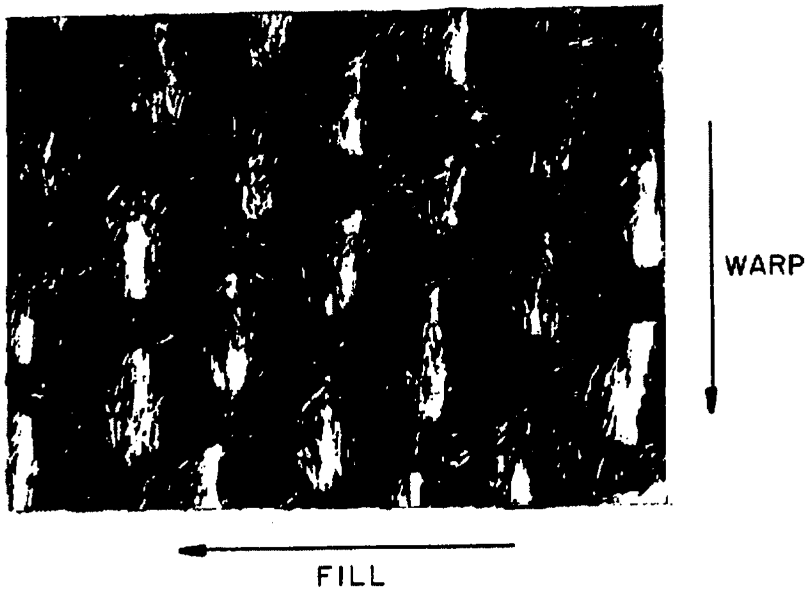


FIG. 6A

FIG. 6B

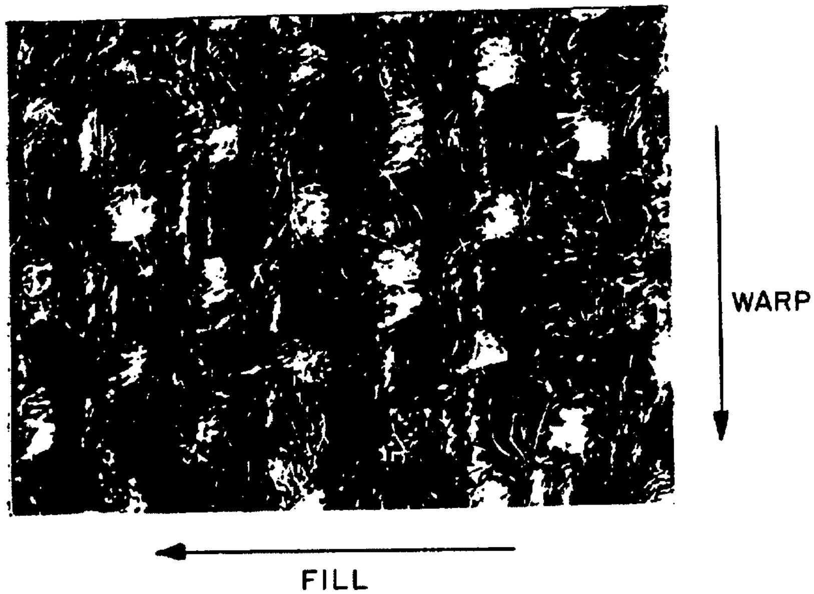


FIG. 7A

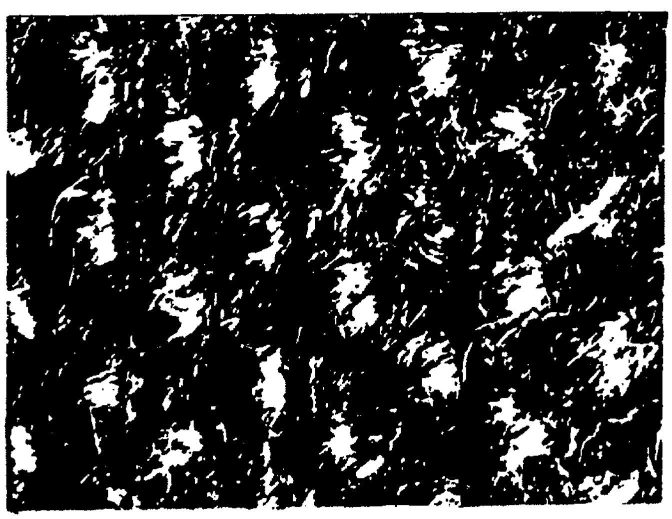


FIG. 7B

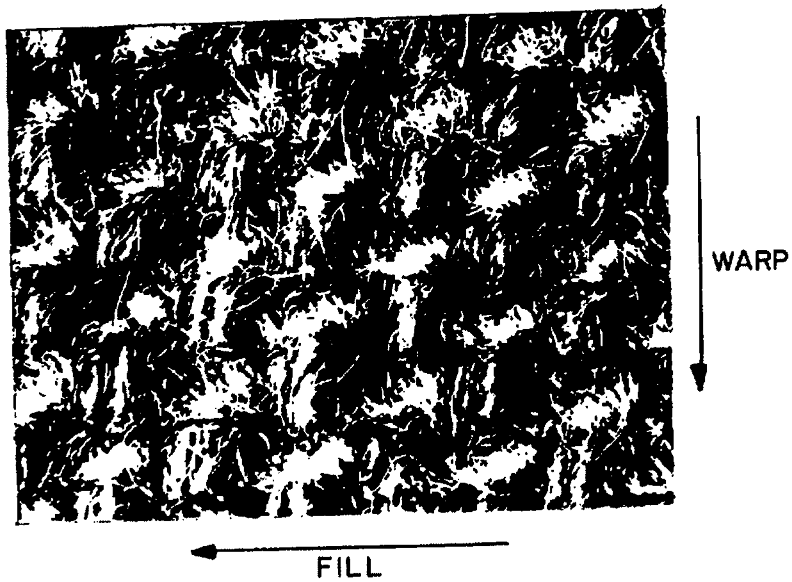


FIG. 8A

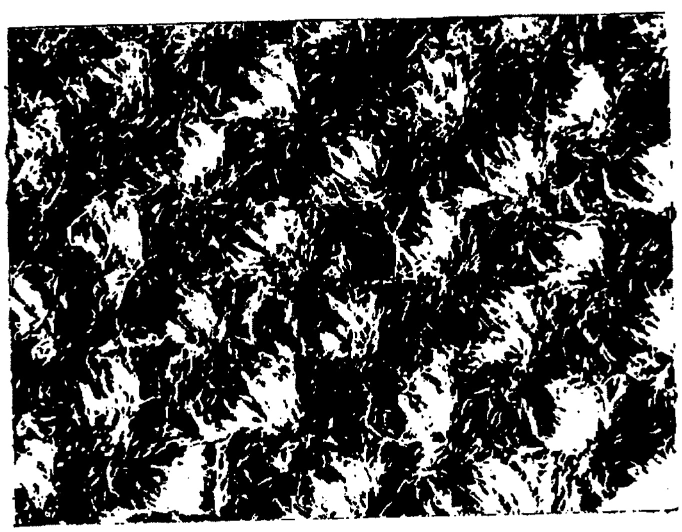


FIG. 8B

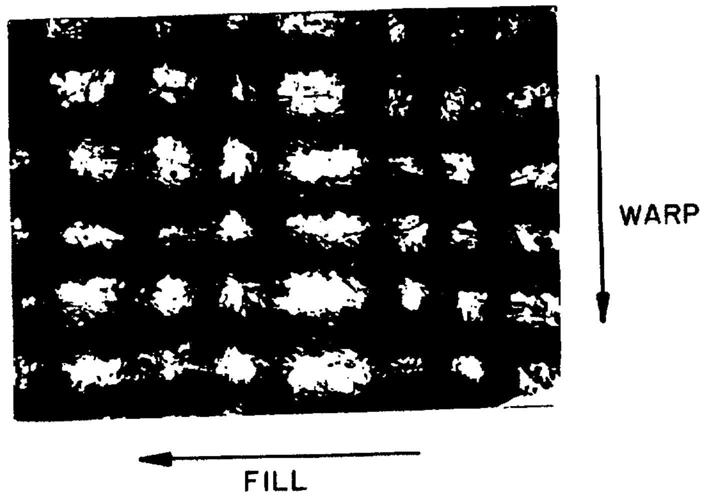


FIG. 9A

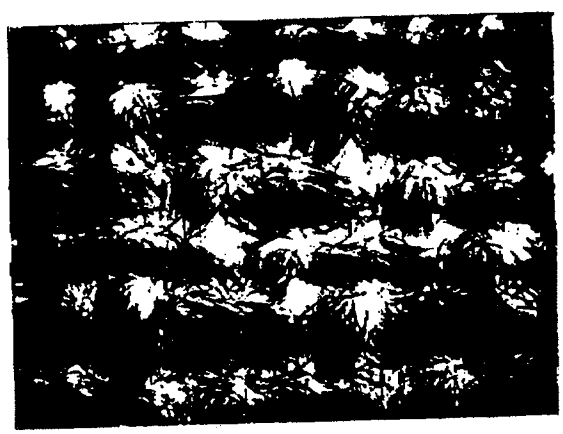


FIG. 9B

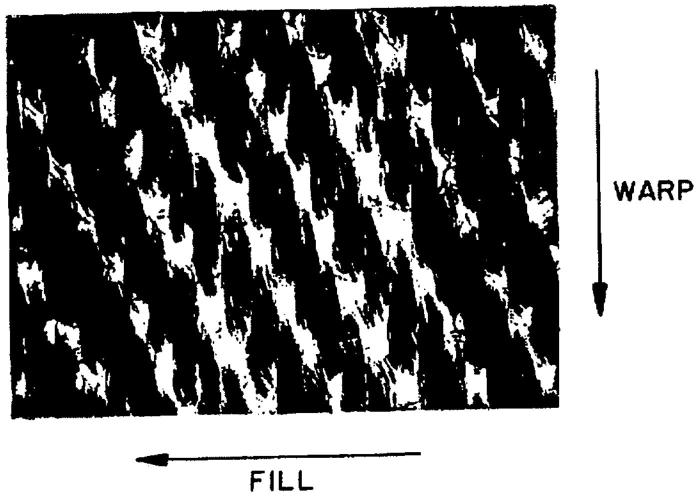


FIG. 10A

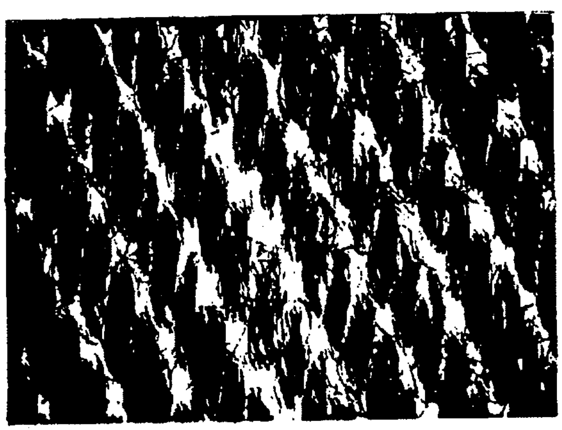


FIG. 10B

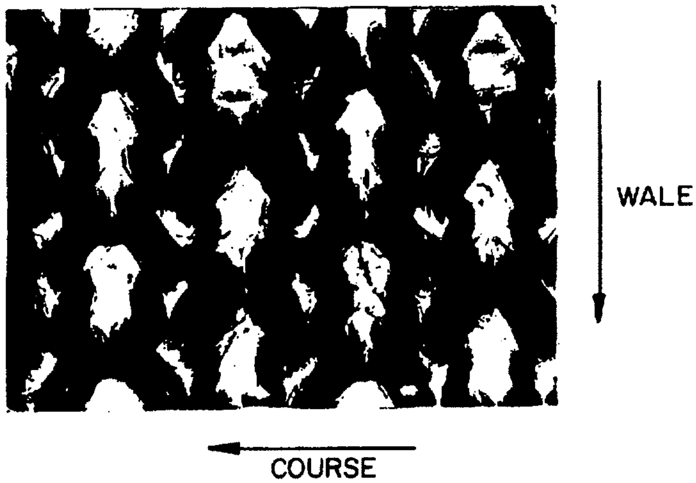


FIG. 11A

FIG. 11B

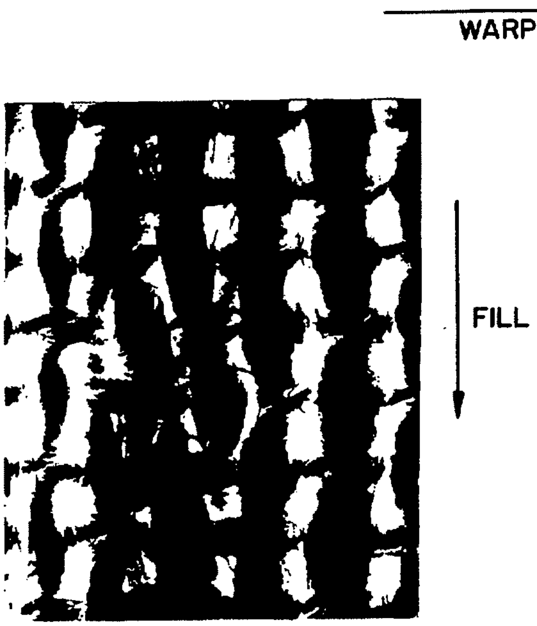


FIG. 12A

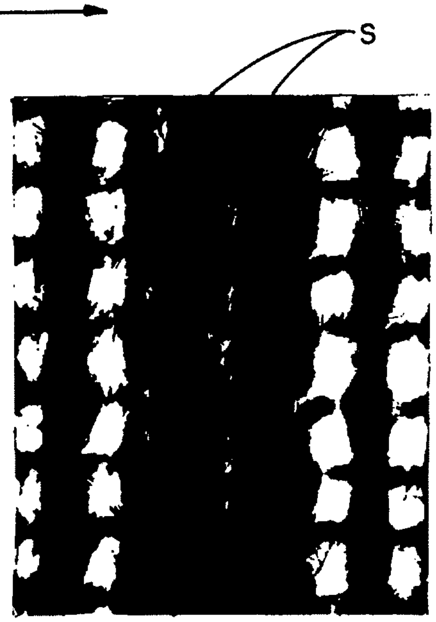


FIG. 12B

FIG. 13A

FIG. 13B

FIG. 14A

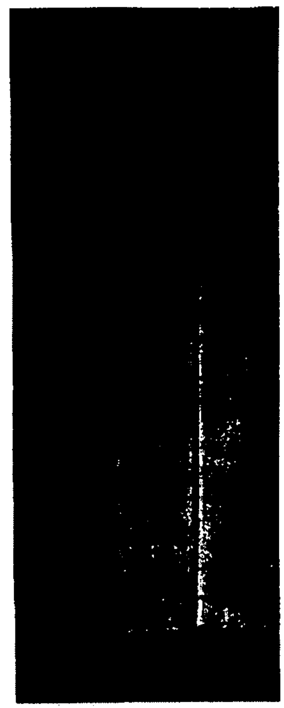


FIG. 14B

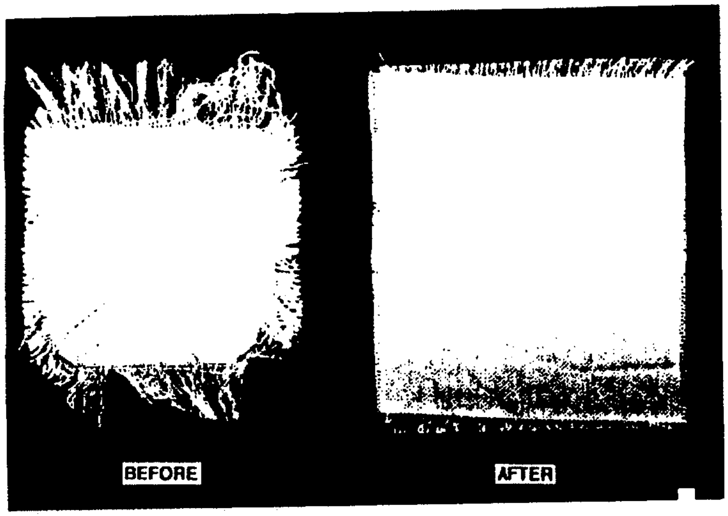


FIG. 15A

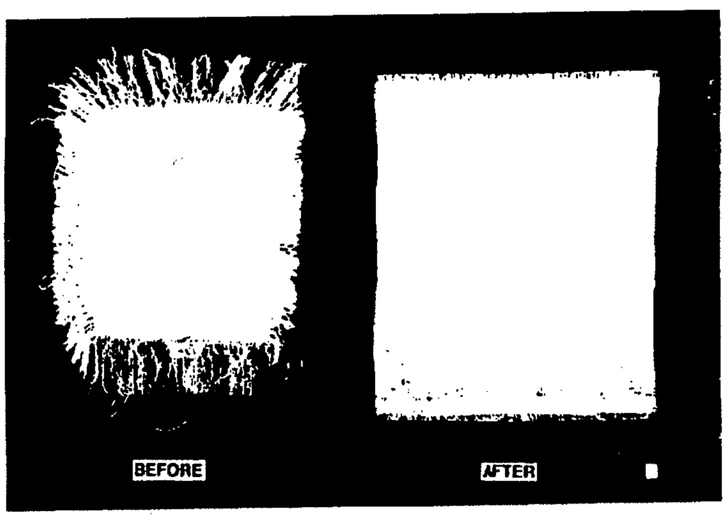


FIG. 15B

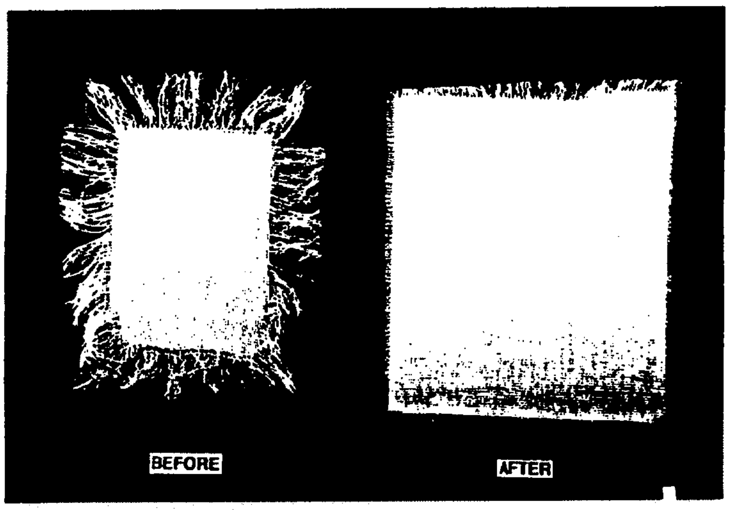


FIG. 15C

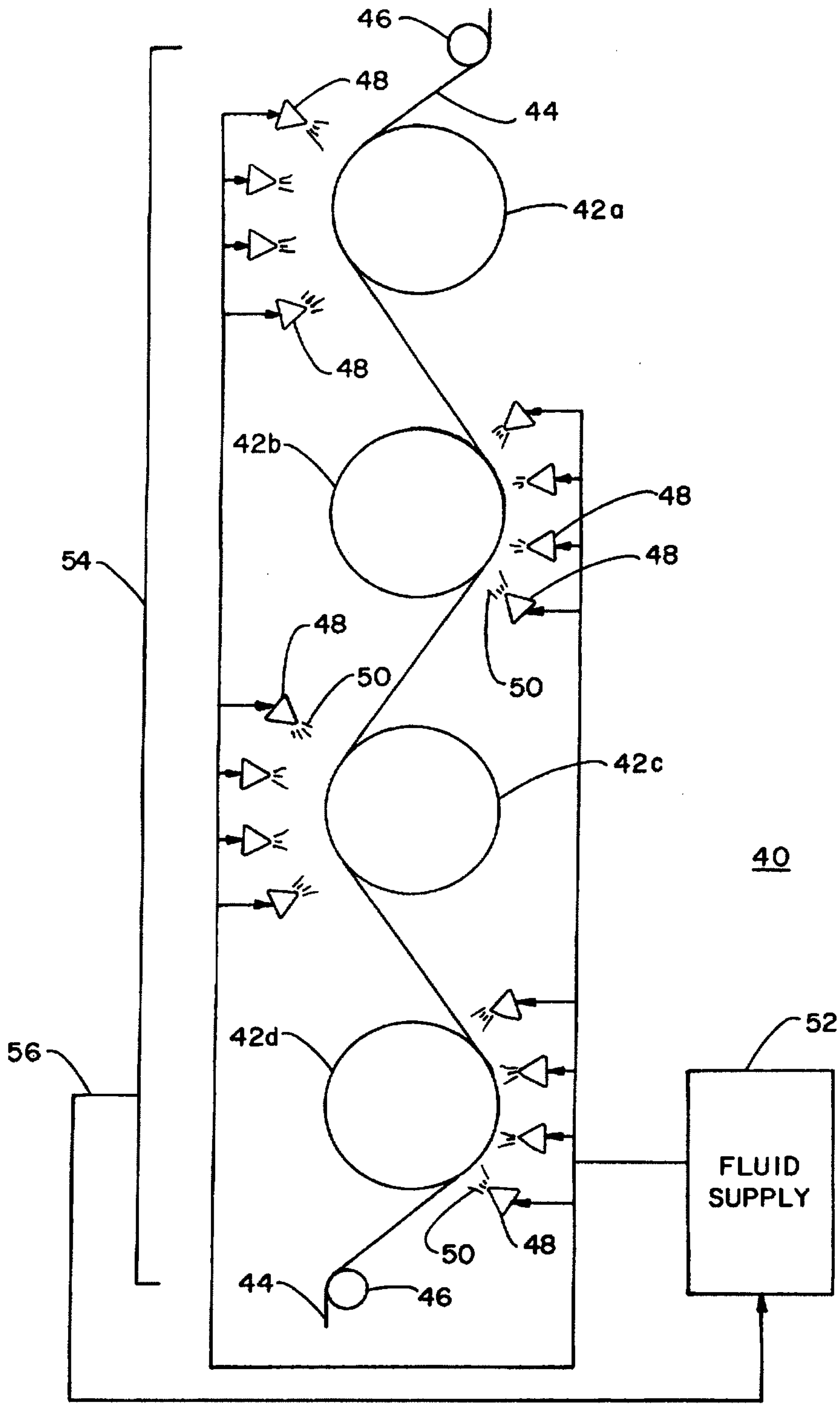

46
48
44
42a
48
42b
48
48
54
48
50
50
42c
40
52
56
42d
FLUID SUPPLY
50
48
44
46

FIG. 16

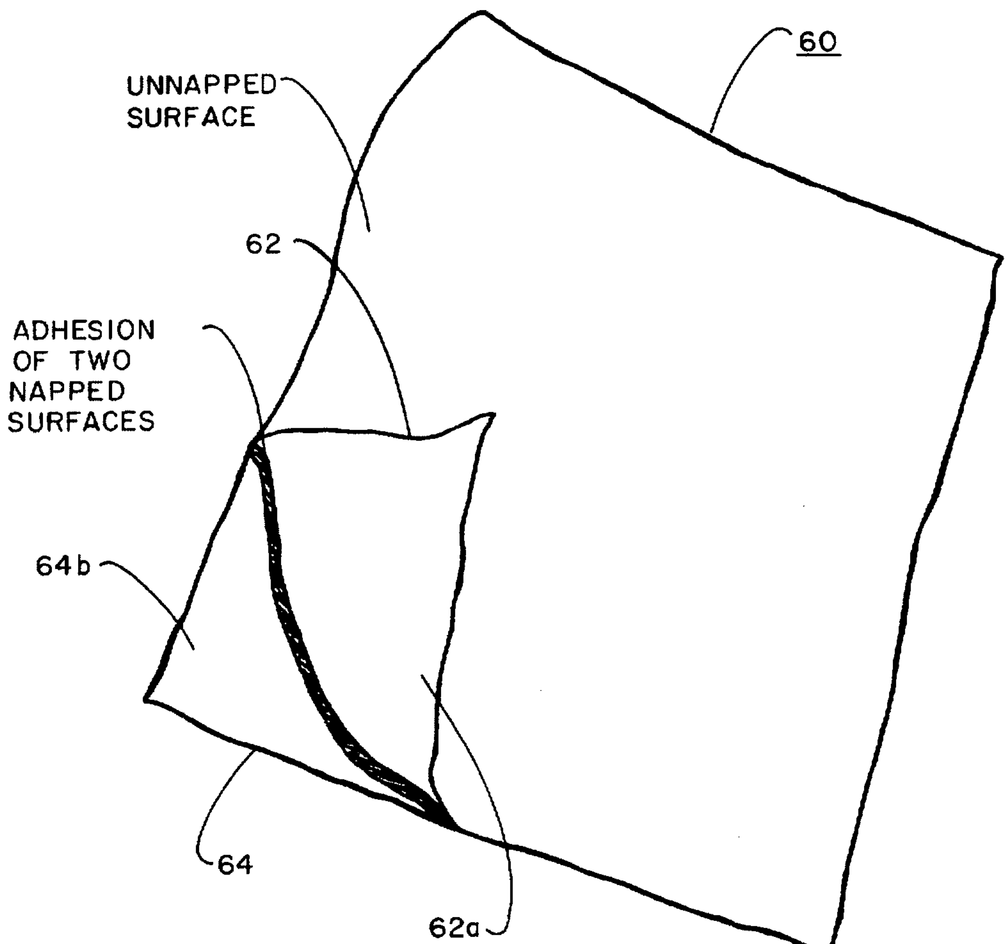

60
UNNAPPED SURFACE
62
ADHESION OF TWO NAPPED SURFACES
64b
64
62a

FIG. 17